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VULNERABILITY OF DRY BAYS ADJACENT TO FUEL TANKS UNDER HORIZONTAL GUNFIRE

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Air Force Aero Propulsion Laboratory
Wright-Patterson Air Force Base, Ohio

March 1973

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TECHNICAL REPORT AFAPL-TR-72-83

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This report deals with the relative vulnerability to incendiary action of dry bays adjacent to fuel tanks as a function of fuel type. Cal .50 API horizontal gunfire was the threat; a high level of simulation was achieved by having air flow external to and in the dry bays. The results of a wide range of test conditions are presented. The overall conclusion of the investigation was that JP-8 fuel is less susceptible to fire and explosion induced by gunfire and should produce less aircraft structural damage than JP-4.

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FOREWORD

This report was prepared by Robert G. Clodfelter of the Fire Protection Branch, Fuels and Lubrication Division, Air Force Aero Propulsion Laboratory. The work reported herein was accomplished under Project 3048, "Fuels, Lubrication, and Fire Protection," Task 304807, "Aerospace Vehicle Fire Protection."

This report covers research accomplished from March 1969 through October 1971 and was submitted by the author 21 April 1972.

The author wishes to acknowledge the valuable assistance and contributions of the following: Mr. V. Balachandran, University of Dayton, for assisting with the statistical analysis and Mr. S. Shook, Mr. R. Lillie, and Mr. D. Tolle, Fire Protection Branch, for their efforts in data reduction. Special thanks is given to Mr. J. O'Neill, Federal Aviation Administration, for conducting the test program at the National Aviation Facilities Experimental Center, Atlantic City, New Jersey under Air Force Delivery Order F33615-67-M-5000.

This technical report has been reviewed and is approved.

C.R. Hudson

C. R. HUDSON
Chief, Fuels and Lubrication Division

ABSTRACT

This report deals with the relative vulnerability to incendiary action of dry bays adjacent to fuel tanks as a function of fuel type. Cal .50 API horizontal gunfire was the threat; a high level of simulation was achieved by having air flow external to and in the dry bays. The results of a wide range of test conditions are presented. The overall conclusion of the investigation was that JP-8 fuel is less susceptible to fire and explosion induced by gunfire and should produce less aircraft structural damage than JP-4.

TABLE OF CONTENTS

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LIST OF ILLUSTRATIONS

LIST OF TABLES

SECTION I

INTRODUCTION

During March 1969 an extensive gunfire test program to evaluate the vulnerability of JP-4 and JP-8 fuels to external fires induced by incendiary gunfire was initiated with FAA (NAFEC), Atlantic City, New Jersey, by redirection of effort under an existing Delivery Order with the AFAPL. The term external fires refers to sustained burning outside the fuel tank (i.e., void space, dry bay areas) either within or outside the simulated aircraft structure. The program with the FAA represented an extension of a small-scale liquid space gunfire test effort conducted in-house by the Air Force Aero Propulsion Laboratory in 1968. During this preliminary testing, the low volatility fuel, JP-8, exhibited external sustained fires only 3.1% of the time, whereas the standard Air Force fuel, JP-4, sustained fires 68.6% of the time. The test article used in the initial program is shown in Figure 1 and details are given in Reference 1.

The FAA program used three larger replica test tanks with more realistic configurations and control of fuel system operating parameters (such as internal pressurization) and considered the effects of internal dry bay ventilation rates as well as airflow exterior to the simulated fuselage on the ignitability, flame propagation, and flame sustainment properties of JP-4 and JP-8 fuels. The FAA long-range gunfire test program involves several phases, but initial emphasis was directed to the fuselage replica tanks and the relative vulnerability of JP-4 and JP-8 fuels.

The purpose of this report is to provide a detailed assessment of the horizontal gunfire tests conducted by the FAA through June 1971.

The results presented herein include a refinement and an extension of the information given in AFAPL-TR-70-93 "AFAPL Aircraft Fire Test Program with FAA 1967-1970," dated June 1971.

Figure 1. Initial Test Article (17-Gallon Tank)

SECTION II

EXPERIMENTAL DESIGN

Several items must be considered in designing a gunfire test program to assess aircraft survivability/vulnerability. All programs have cost and time constraints. One approach that may be taken is to strive for a very high degree of simulation. Real aircraft fuel tanks may be used, but the threat and operational environment must also be simulated. Even with a very high degree of simulation of this environment, the test results are still estimates based on statistical sampling and can be statistically valid only with sufficient sampling. Many tests with a high level of simulation may conflict with the cost-time constraints; therefore, the scope of the test effort may have to be restricted in order to obtain valid results. Unfortunately, if the scope is too limited, making general conclusions applying to conditions not specified in the test would be impossible. This is true because high variance is associated with most response variables which quantify the projectile-fuel tank interaction, regardless of the level of simulation achieved in the test program.

The approach taken in this effort was to design an experiment which would be statistically valid yet provide general conclusions. Trade-offs were made in the level of simulation in order to accomplish as many tests under as wide a range of conditions as possible. The number of times each set of test conditions was repeated was based on statistical principles and a projection of the expected test results. In other words, if a large difference in response was expected between two sets of test conditions, a smaller number of repeats would be required than if only a small difference was expected. An example which illustrates this point is presented in Appendix IV. All factors which were not controllable, such as ambient temperature, projectile dynamics, etc., should have entered into the program in a random way. Complete randomization of the factors would have made the test sequencing unmanageable, and trade-offs again were required; however, some effort to randomize the uncontrollable parameters was included in the program to ensure that the test results were not biased by the uncontrollable factors.

SECTION III

TEST DESCRIPTION

The objective of the test program was to determine the relative vulnerability of JP-4 and JP-8 fuels to fires in areas outside the fuel tank (i.e., void space, and dry bay areas--also referred to as standoff). For most of the test program, the only variables were fuel type, void space volume, void space ventilation, and external airflow. All other factors were controlled at a fixed value. The following test conditions were established for the initial phase of the test program:

1. Fuels: JP-4 and JP-8 (118°F flash point)
2. Projectile type and velocity: Cal .50 API, 2400 ft/sec.
3. Projectile trajectory: Horizontal, impact angle of 30°.
4. Tank volume: Approximately 90 gallons
5. Fuel temperature: 90°F ± 5
6. Fuel tank pressure: 5 psig
7. Fuel height: 18 inches
8. Impact point: Center of liquid, approximately 9 inches below the fuel/ullage interface.
9. Ullage: 25% of tank volume
10. External air velocity: 0, 90, 125, and 300 knots
11. Standoff distance (striker plate to tank distance - also referred to as void space): 1, 4, and 9 inches
12. Void space ventilation:
    a. 18 ACPM* at 90 knots external airflow and 4 inch test article
    b. 75 ACPM at 90 knots external airflow and 4 inch test article
    c. 58 ACPM at 300 knots external airflow and 4 inch test article
    d. 180 ACPM at 300 knots external airflow and 4 inch test article
    e. 23 ACPM at 90 knots external airflow and 9 inch test article
    f. 96 ACPM at 90 knots external airflow and 9 inch test article

g. 101 ACPM at 300 knots external airflow and 9 inch test article.

h. 325 ACPM at 300 knots external airflow and 9 inch test article.

*ACPM - Air Changes Per Minute

The projectile velocity (2400 ft/sec) and striker plate (first impact surface consisting of 2 plates made of 0.125" and 0.090" 2024T3 aluminum) configuration were selected to give maximum incendiary functioning in the void volume. These were selected by making two shots into each of three standoff distances (1, 4, and 9 inches) at three projectile velocities (1800, 2400, and 2900 ft/sec) and noting the incendiary burn times. From the 18 shots, a projectile velocity of 2400 ft/sec produced the longest incendiary burn time (10 to 18 milliseconds, on the average). The biggest ignition source possible with a Cal .50 API, therefore, was available to ignite any fuel in the void space. External airflow around the test article was generated by ducting fan air from a TF-33 engine.

In addition to the above, a few tests were conducted with other test conditions: (1) polyurethane flame-arresting foam in the dry bay; (2) polyurethane flame-arresting foam in the fuel tank; (3) fuel temperature other than 90°F; (4) fuel tank pressure other than 20 psia; and (5) various sizes of dry bays on both the projectile exit side and projectile entrance side of the test article.

Photographic data was recorded by two cameras at 3500 and 7000 frames per second, color film. The test article was viewed through the plexiglass top plate. Overall film coverage was provided by a camera operating at 500 frames per second.

An overall view of the test range is given in Figure 2, and a typical test article designed to simulate a fuselage fuel tank is shown in Figure 3. Figure 4 shows the various test article configurations and gives a summary of the test conditions. Detailed test conditions and results are presented in Appendix I; additional background information on the test procedures are given in References 2 and 3. Appendixes II and III present two potential problem areas considered prior to detailed analysis of the test results. Appendix V gives the properties of the two fuels used in the test program.

Figure 2. Overall View of Engine, Test Weapon, and Test Article

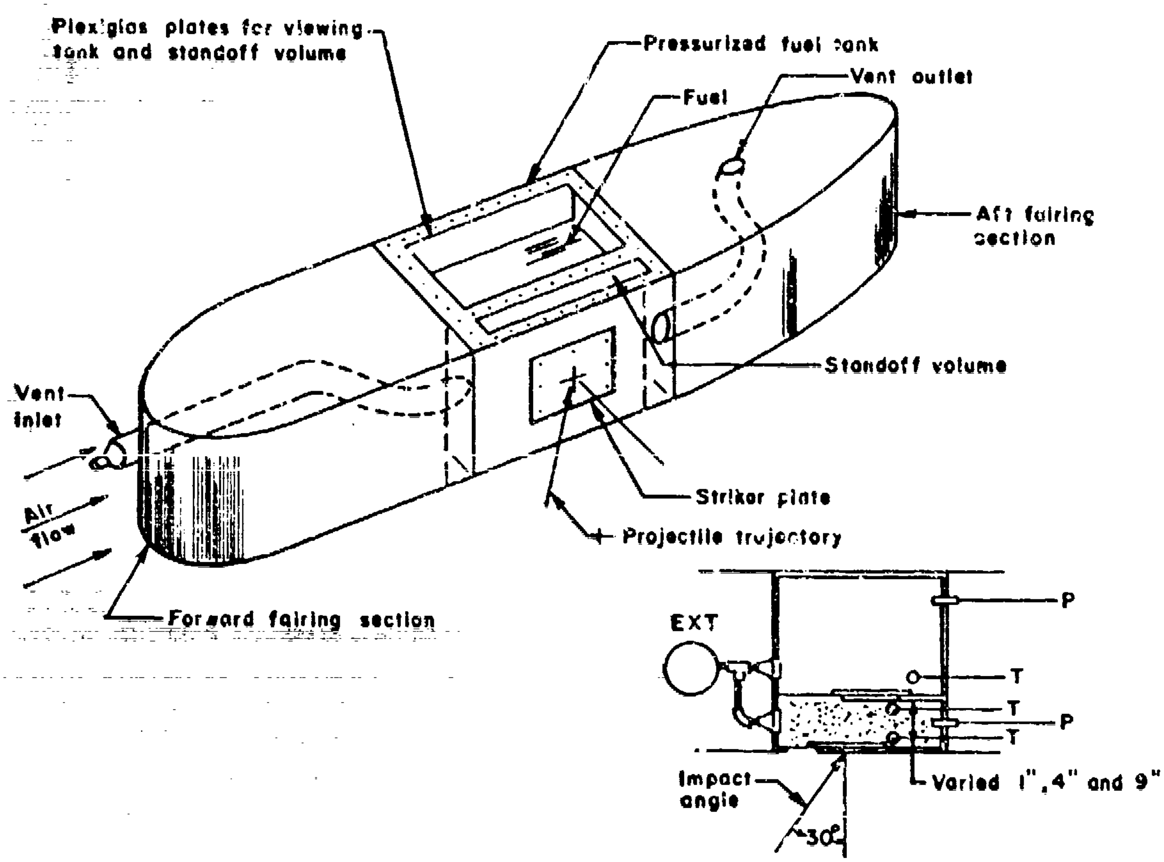
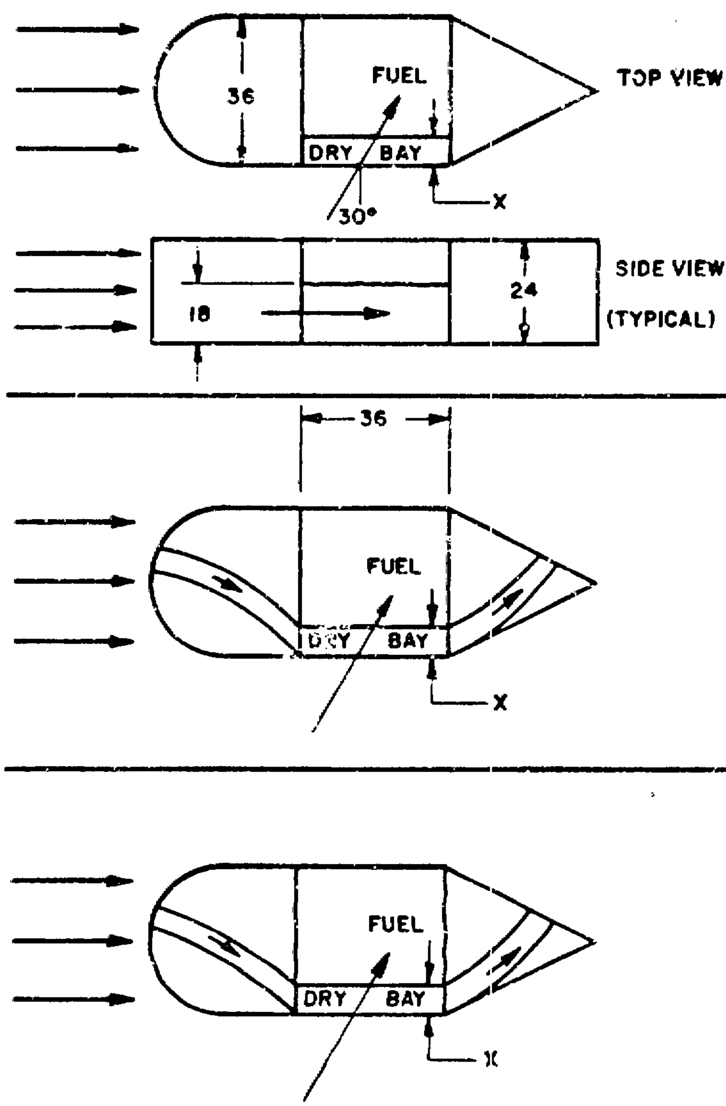


Figure 3. FAA Gunfire Test Article



Tests 1 – 72

No exit hole

X = 1", 4", and 9", vol. = 0.44, 2.18, and 3.77 ft^3

No dry bay air changes
External air flow: 0, 152, and 210 fps
Fuel temperature: 90°F
Tank pressure: 20 psia

Tests 73 – 180

No exit hole

X = 4" and 9", vol. = 2.18 and 3.77 ft^3

Dry bay ACPM: 23, 101, 96, 325, and 18, 58, 75, 180
External air flow: 152 and 507 fps
Fuel temperature: 90 and 75°F
Tank pressure: 20 and 14.7 psia

Tests 181 – 186

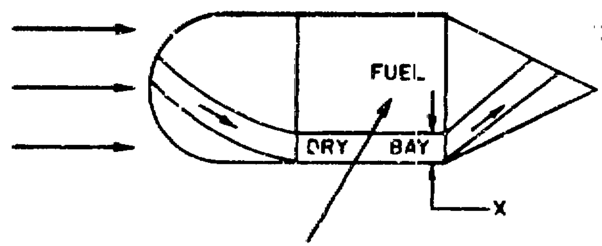
10 ppi (1.86 lb/ft^3) foam in dry bay

No exit hole

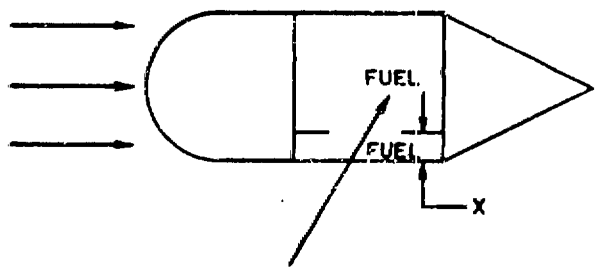
X = 4", vol. = 2.18 ft^3

Dry bay ACPM: 18
External air flow: 152 fps
Fuel temperature: 90°F
Tank pressure: 20 psia

Figure 4. Summary of Test Conditions



Tests 187 – 192
10 ppi (1.86 lb/ft^3) foam in fuel tank
No exit hole
X = 4", vol. = 2.18 ft^3
Dry Bay ACPM: 18
External air flow: 152 fps
Fuel temp: 90°F
Tank pressure: 14.7 psia
2" fuel depth



Tests 193 – 198

No exit hole

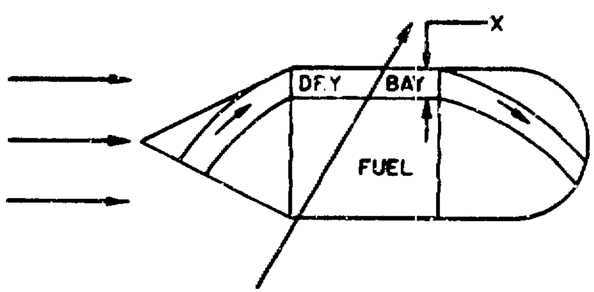
No dry bay

X = 9", vol. = 3.77 ft^3

External air flow: 152 fps

Fuel temp. : 90°F

Tank pressure : 20 psia



Tests 201 – 212

X = 9", vol. 3.77 ft^3

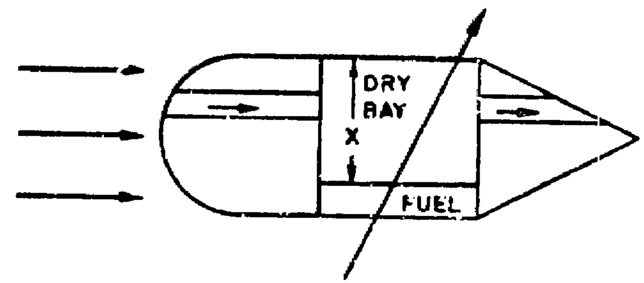
Dry bay ACPM: 0 and 23

External air flow: 152 fps

Fuel temp.: 90°F

Tank pressure: 14.7 psia

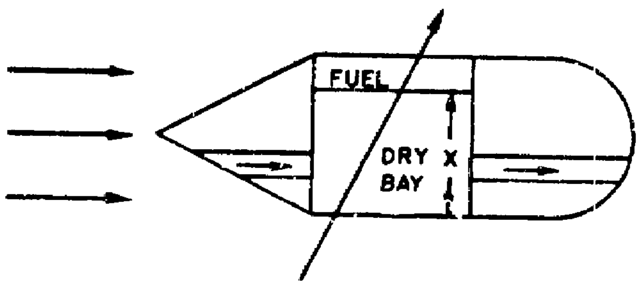
Figure 4. Continued



Tests 219 – 230

X = 27", vol. = 9.92 ft^3

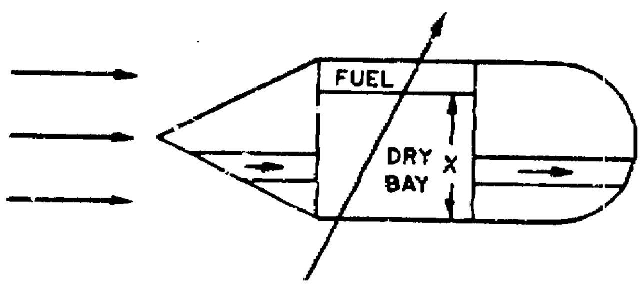
Dry bay ACPM: 0, 7, and 33
External air flow: 152 fps
Fuel temp.: 90°F
Tank pressure: 14.7 psia



Tests 231 – 242

X = 27", vol. = 9.92 ft^3

Dry bay ACPM: 0, and 7
External air flow: 152 fps
Fuel temp.: 90°F
Tank pressure: 14.7 psia



Tests 243 – 254

X = 27", vol. = 19.9 ft^3 (Includes 10 ft^3 hat section, coded as 27" H in data)
Dry bay ACPM: 0, 4
External air flow: 152 fps
Fuel temp.: 90°F
Tank pressure: 14.7 psia

Figure 4. Continued

SECTION IV

STATISTICAL PROCEDURES

1. STATISTICAL METHODS

The first step in the analysis of the test results was to compare the recorded responses for the two fuels (JP-4 and JP-8) under identical initial conditions. Statistical methods were used in the comparison to assess the question, "If a difference between the response variables for the two fuels is noted, is the difference small enough that it could have occurred by chance or is it so large that it most probably is a true measure of the difference between the two fuels?" The following statistical expressions were used in this analysis (the reader may refer to the many textbooks on the subject for details).

The sample mean $\overline{X} = \frac{1}{n} \sum_{i=1}^{n} X_i$, where $X_1, X_2 \ldots X_n$ denote the responses of the random variable X, and n is the size of the sample, provides an unbiased and minimum variance estimate on the population mean μ, which is unknown.

The sample variance $S^2 = \left[\sum_{i=1}^{n} (X_i - \overline{X})^2 \right] \Big/ (n - 1)$

provides an unbiased estimate of the population variance σ^2.
Morever if S_1^2 and S_2^2 are two independent estimates of the same unknown, σ^2 based on n_1 and n_2 samples, respectively, then

$$F = S_1^2 / S_2^2 \quad \text{or} \quad S_2^2 / S_1^2$$

(the ratio selected in such a way that the larger S^2 is in the numerator).

This yields an F with $n_1 - 1$ and $n_2 - 1$ degrees of freedom for the numerator and denominator, respectively, assuming $S^2_1 > S^2_2$, which could be compared with F distribution values for homogeneity of variance.

The T test which was used to test for the significant difference of means was based on the assumption that there was "homogeneity of variance." Thus, the F ratio was used as a measure to check the validity of this underlying assumption. Values of the F ratio near one are desired. Once such an assumption is established as valid, then any difference in the data is solely due to the difference in means. In a large number of cases in Table I, the F ratio was not significant, which ensured homogeneity of variances. Hence we made a general assumption of "homogeneity of variance," which enabled us to use the T test for the difference in means.

The criterion for comparing the means was the Student T test.

$$T = \frac{\left| \bar{X}_1 - \bar{X}_2 \right|}{\left(\frac{(n_1 - 1)\ \sigma_1^2 + (n_2 - 1)\ \sigma_2^2}{n_1 + n_2 - 2} \right)^{1/2}} \left(\frac{n_1 n_2}{n_1 + n_2} \right)^{1/2}$$

A T_c value was chosen to test the results. If the calculated T is less than T_c, there is probably no significant difference between the means. If the calculated T is larger than T_c, the two means are not necessarily different, but it provides a strong argument in favor of a difference.

A T_c value associated with the 95 percentile point was used in the comparison. This is equivalent to a 10% error for the "two-tail" problem of interest; that is, if 100 sets of response variables are to be compared, at least 90 sets would verify the conclusion and no more than 10 sets would not. Values of T_c are given in most statistical reference books as a function of degree of freedom (DF = $n_1 + n_2 - 2$) where, for our tests, n_1 is the number of tests with JP-4, and n_2 the number with JP-8.

The results of the statistical analysis for the two fuels are given in Tables I through V. Reference Appendix IV, which illustrates the inability to show a difference between means when that difference is small and only a limited number of tests are conducted.

2. TEST DESCRIPTION CODE

The following codes designate the items given under test conditions (a,b,c,d,e,f) in Tables I thru V.

a = Fuel Type (4 = JP-4, 8 = JP-8)

b = Fuel Temperature (°F ± 5 °F)

c = Standoff Distance (inches) ex. 27 = 27 inches standoff front side
27B = 27 inches standoff back side
27H = 27 inches standoff front side with hat section

d = External air flow (Knots ± 10 knots)

e = Air changes per minute in standoff (ACPM ± 2 ACPM)

f = Initial fuel tank pressure (psia ± 2 psi)

3. ASSESSMENT OF RESULTS

The following discussion of the test results considers both the statistical information of Tables I thru V and other factors of the "real world" which could not be included in the statistical analysis.

a. Standoff Fire Duration (Table 1)

From the "real world" point of view, it is possible for the Standoff Fire Duration to be dependent on the fuel type. Unfortunately, the total Standoff Fire Duration was unknown for several tests because the data camera ran out of film before the fire stopped. This occurred during 21 of 98 tests with JP-4 and 29 of 92 tests with JP-8, so about 1/4 of the input data indicated less than the actual standoff fire duration. With this limitation, the following general observations were made.

a. At very low dry bay ACPM, the standoff fire duration for JP-8 was 2 to 5 times longer than for JP-4 (typically 350 vs 80 msec). JP-4 burns faster and thus depletes the available oxygen faster.

TABLE I

STANDOFF FIRE DURATION FOR JP-4 vs. JP-8 FUELS (MSEC)

No.	Test Description a b c d e f	n		VARIANCE (σ^2)		MEAN ($\bar{X}$)		F Ratio	T	T_c*	REMARKS
		JP-4	JP-8	JP-4	JP-8	JP-4	JP-8				
1	(-,90,9,0,0,20)	4	5	2211	61,627	71	310	27.9	1.68	1.90	
2	(-,90,9,90,0,20)	5	5	3724	8677	97	432	2.3	6.73**	1.86	
3	(-,90,9,90,23,20)	6	5	3190	436	312	279	7.3	1.24	1.83	
4	(-,90,9,90,96,20)	6	3	4217	1,318,169	207	1051	431.2	1.65	1.90	
5	(-,90,9,300,101,20)	6	6	9077	8103	239	262	1.1	0.43	1.81	
6	(-,90,91,300,325,20)	6	4	8200	554	183	65	14.8	2.53**	1.86	
7	(-,90,4,0,0,20)	6	6	35442	4116	252	403	8.5	1.87**	1.81	
8	(-,90,4,90,0,20)	5	6	4435	3975	75	330	1.1	6.50**	1.83	
9	(-,90,4,90,18,20)	5	4	18,404	8024	204	285	2.29	1.03	1.90	
10	(-,90,4,90,75,20)	3	4	3325	3,738,790	293	1333	1124	.91	2.02	
11	(-,90,4,300,58,20)	4	3	1304	4177	331	350	3.2	.51	2.02	
12	(-,50,4,300,180,20)	4	4	10,079	3,799,744	236	2580	377	2.40**	1.94	
13	(-,90,1,0,0,20)			Insufficient		Data					
14	(-,90,1,90,0,20)			Insufficient		Data					
15	(-,75,9,90,25,20)	2	2	6161	6845	257	378	1.1	1.50	2.92	

TABLE I (CONTINUED)

No.	Test Description a b c d e f	n JP 4	n JP-8	VARIANCE (σ^2) JP-4	VARIANCE (σ^2) JP-8	MEAN ($\bar{X}$) JP-4	MEAN ($\bar{X}$) JP-8	F Ratio	T	T_c*	REMARKS
16	(-,90,9,90,23,15)	4	4	13.318	48,003	397	269	3.6	1.03	1.94	
17	(-,75,9,90,97,20)	3	2	2,473	13,945	249	380	5.6	1.80	2.35	
18	(-,90,9,90,97,15)	2	3	288	4,722	518	422	16.4	1.85	2.35	
19	(-,90,4,90,18,20)			Insufficient		Data					10 PPI foam in standoff
20	(-,90,4,90.18,15)	3	3	56,785	176	169	477	322.0	2.24	2.13	10 PPI foam in tank
21	(-,90,0,90,0,20)	3	3		N/A						No standoff
22	(-,90,9B,90,0,15)	3	3	0	0	0	0	U	U	2.13	9" standoff backside
23	(-,90,9B,90,23,15)	3	3	0	0	0	0	U	U	2.13	9" standoff backside
24	(-,90,27B,90,0,15)	3	3	0	8.3	0	1.7	U	1.00	2.13	27" standoff backside
25	(-,90,27B,90,7,15)	3	2	50,181	45,000	129	150	1.1	.10	2.35	27" standoff backside
26	(-,90,27B,90,33,15)	3	3	0	44,652	0	122	U	1.00	2.13	27" standoff backside
27	(-,90,27,90,0,15)	3	3	1.716	42,245	315	119	24.6	1.62	2.13	
28	(-,90,27,90,7,15)	3	3	34,961	35,557	215	217	1.02	0.02	2.35	
29	(-,90,27H,90,0,15)			Insufficient		Data					27" standoff with hat section
30	(-,90,27H,90,4,15)			Insufficient		Data					27" standoff with hat section

*T_c = T value at 25.0% (10% error - two tail)

**Values showing statistical differences

TABLE II

INCENDIARY BURN TIMES IN STANDOFF FOR JP-4 vs. JP-8 FUELS (MSEC)

No.	Test Description a b c d e f	n		VARIANCE (σ^2)		MEAN ($\overline{X}$)		F Ratio	T	T_c*	REMARKS
		JP-4	JP-8	JP-4	JP-8	JP-4	JP-8				
1	(-,90,9,0,0,20)	6	5	23	459	7	29	20.4	2.40**	1.83	
2	(-,90,9,90,0,20)	6	5	306	437	22	52	1.4	2.66**	1.83	
3	(-,90,9,90,23,20)	6	5	4	64	9	14	14.9	1.69	1.83	
4	(-,90,9,90,96,20)	6	4	125	0.7	21	7	186.9	2.48**	1.86	
5	(-,90,9,300,101,20)	6	6	1	35	8	13	29.1	2.10**	1.81	
6	(-,90,9,300,325,20)	6	4	89	234	20	27	2.6	.97	1.86	
7	(-,90,4,0,0,20)	6	6	82	37	32	[illegible]	2.2	4.61**	1.81	
8	(-,90,4,90,0,20)	5	6	148	0.4	25	8	370.8	3.53**	1.83	
9	(-,90,4,90,18,20)	5	5	17	2	10	7	7.9	1.42	1.86	
10	(-,90,4,90,75,20)	5	4	3	30	10	11	11	.22	1.90	
11	(-,90,4,300,58,20)	4	4	1	0.7	7	3	2	5.66**	1.94	
12	(-,90,4,300,180,20)	4	4	5	16	9	15	3.2	2.43**	1.94	
13	(-,90,1,0,0,20)	4	5	393	839	47	33	2.1	0.78	1.90	
14	(-,90,1,90,0,20)	3	4	86	0.7	12	2	127.5	2.14**	2.02	
15	(-,75,9,90,23,20)	2	3	5	4	10	8	1.0	0.96	2.35	

TABLE II (CONTINUED)

No.	Test Description a b c d e f	n JP-4	n JP-8	VARIANCE (σ^2) JP-4	VARIANCE (σ^2) JP-8	MEAN ($\bar{X}$) JP-4	MEAN ($\bar{X}$) JP-8	F Ratio	T	T_c*	REMARKS
16	(-,90,9.90,23,15)	4	4	2	3	10	8	1.6	1.44	1.94	
17	(-,75,9,90,97,20)	3	2	0.3	13	12	10	37.5	1.13	2.35	
18	(-,90,9,90,97,15)	3	3	2	4	7	8	1.9	0.22	2.13	
19	(-,90,4,90,18,20)			Insufficient	Data						10 PPI foam in standoff
20	(-,90,4,90,18,15)	3	3	2	1	7	8	2.3	.63	2.13	10 PPI foam in tank
21	(-,90,0,90,0,20)				N/A						No standoff
22	(-,90,9B,90,0,15)	3	3	0	0	0	0	U	U	2.13	9" S.O. backside
23	(-,90,9B,90,23,15)	3	3	0	0	0	0	U	U	2.13	9" S.O. backside
24	(-,90,27B,90,0,15)	3	3	0.3	0.3	0.3	2	1.0	2.83**	2.13	27" S.O. backside
25	(-,90,27B,90,7,15)	3	2	7	.5	3	4	14	.25	2.35	27" S.O. backside
26	(-,90,27B,90,33,15)	2	2	8	0	2	0	U	1.0	2.92	27" S.O. backside
27	(-,90,27,90,0,15)	3	3	1	19	7	5	14.3	0.90	2.13	
28	(-,90,27,90.7,15)	3	3	16	.3	4	4	49	00	2.13	
29	(-,90,27H,90,0,15)			Insufficient	Data						27" standoff with hat section
30	(-,90,27H,90.4,15)			Insufficient	Data						27" standoff with hat section

*T_c = T value at 95.0% (10% error - two tail)

**Values showing statistical difference

TABLE III

INITIAL EXTERNAL FUEL SPRAY TIME FOR JP-4 vs. JP-8 FUEL (MSEC)

No.	Test Description a b c d e f	n		VARIANCE (σ^2)		MEAN ($\overline{X}$)		F Ratio	T	T_c^*	REMARKS
		JP-4	JP-8	JP-4	JP-8	JP-4	JP-8				
1	(-,90,9,0,0,20)	5	5	9,435	241,065	99	1,028	25.6	4.15**	1.86	
2	(-,90,9,90,0,20)	5	5	141,879	88,872	401	532	1.6	0.61	1.86	
3	(-,90,9,90,23,20)	3	2	25,541	242	219	316	105.5	.82	2.35	
4	(-,90,9,90,96,20)	6	4	10,178	25	126	34	407.1	1.80	1.86	
5	(-,90,9,300,101,20)	6	6	7,131	5,801	121	126	1.2	0.11	1.81	
6	(-,90,9,300,325,20)	6	4	25,902	684	121	103	37.9	.22	1.86	
7	(-,90,4,0,0,20)	6	6	50,244	187,793	309	587	3.7	1.40	1.81	
8	(-,90,4,90,0,20)	5	6	49,197	43,620	249	845	1.1	4.59**	1.83	
9	(-,90,4,90,18,20)	6	6	180	3,209	61	57	17.8	0.15	1.81	
10	(-,90,4,90,75,20)	5	4	3,930	9,559	86	191	2.4	1.97**	1.90	
11	(-,90,4,300,58,20)	4	2	321	0	39	22	U	1.23	2.13	
12	(-,90,4,300,180,20)	4	4	172	209	29	37	1.2	0.82	1 94	
13	(-,90,1,0,0,20)	4	5	1,444	523	19	35	2.8	0.78	1.90	
14	(-,90,1,90,0,20)	3	4	508	110,257	46	312	217	1.35	2.02	
15	(-,75,9,90,23,20)	1	3	U	148,933	234	763	U	U	2.92	

TABLE III (CONTINUED)

No.	Test Description a b c d e f	n		VARIANCE (σ^2)		MEAN ($\bar{X}$)		F Ratio	T	T_c*	REMARKS
		JP-4	JP-8	JP-4	JP-8	JP-4	JP-8				
16	(-,90,9,90,23,15)	4	1	2,798	U	276	604	U	U	2.35	
17	(-,75,9,90,97,20)	3	3	132,933	221,449	639	843	1.7	0.59	2.13	
18	(-,90,9,90,97,15)	2	2	20,808	1,976,072	552	2,026	95	1.48	2.92	
19	(-,90,4,90,18,20)	3	2	14,196	2,178	172	113	6.5	0.64	2.35	10 PPI foam in standoff
20	(-,90,4,90,18,15)			Insufficient Data							10 PPI foam in tank
21	(-,90,0,90,0,20)	3	3	0	0	0	0	U	U	2.13	No standoff
22	(-,90,9B,90,0,15)	3	3	0	0	0	0	U	U	2.13	9' standoff backside
23	(-,90,9B,90,23,15)	3	3	0	0	0	0	U	U	2.13	9" standoff backside
24	(-,90,27B,90,0,15)	3	3	0	0	0	0	U	U	2.13	27" standoff backside
25	(-,90,27B,90,7,15)	3	3	0	0	0	0	U	U	2.35	27" standoff backside
26	(-,90,27B,90,33,15)	3	3	0	0	0	0	U	U	2.13	27" standoff backside
27	(-,90,27,90,0,15)			Insufficient Data							
28	(-,90,27,90,7,15)			Insufficient Data							
29	(-,90,27H,90,0,15)			Insufficient Data							27" standoff with hat section
30	(-,90,27H,90,4,15)			Insufficient Data							27" standoff with hat section

*T_c = T value at 95.0% (10% error - two tail)

**Values showing statistical difference

TABLE IV

TIME TO MAXIMUM STANDOFF PRESSURE FOR JP-4 vs. JP-8 FUEL (MSEC)

No.	Test Description a b c d e f	n		VARIANCE (σ^2)		MEAN ($\bar{X}$)		F Ratio	T	T_c*	REMARKS
		JP-4	JP-8	JP-4	JP-8	JP-4	JP-8				
1	(-,90,[illegible],0,0,20)	[illegible]	5	4,203	1,824	58	84	2.3	0.71	1.90	
2	(-,90,9,30,0,20)	6	5	1,359	700	55	77	1.9	1.11	1.83	
3	(-,90,9,90,23,20)	5	5	292	226	33	36	1.3	0.35	1.86	
4	(-,90,9,90,96,20)	6	4	783	78	32	18	10.0	0.94	1.86	
5	(-,90,9,300,101,20)	6	5	305	40	32	29	7.6	0.41	1.83	
6	(-,90,9,300,325,20)	6	3	52	.33	35	26	157.2	2.00**	1.90	
7	(-,90,4,0,0,20)	6	4	78	6,967	27	76	89.3	1.48	1.86	
8	(-,90,4,90,0,20)	3	2	3	41	20	27	13.5	1.81	2.35	
9	(-,90,4,90,18,20)	6	5	1,353	105	58	101	12.9	2.52**	1.83	
10	(-,90,4,90,75,20)	5	4	927	329	83	44	2.8	2.27**	1.90	
11	(-,90,4,300,58,20)	4	4	9	461	68	82	53.2	0.53	1.94	
12	(-,90,4,300,180,20)	4	4	1,622	2,444	57	71	1.5	0.42	1.94	
13	(-,90,1,0,0,20)			Insufficient		Data					
14	(-,90,1,90,0,20)			Insufficient		Data					
15	(-,75,9,90,23,20)	2	3	545	91	48	40	6.0	0.53	2.35	

TABLE IV (CONTINUED)

No.	Test Description a b c d e f	n JP-4	n JP-8	VARIANCE (σ^2) JP-4	VARIANCE (σ^2) JP-8	MEAN ($\bar{X}$) JP-4	MEAN ($\bar{X}$) JP-8	F Ratio	T	T_c*	REMARKS
16	(-,90,9,90,23,15)	4	4	96	355	28	43	3.7	1.41	1.94	
17	(-,75,9,90,97,20)	3	3	17	9	53	47	1.9	1.91	2.13	
18	(-,90,9,90,97,15)	3	3	21	30[illegible]	46	25	14.1	2.06	2.13	
19	(-,90,4,90,18,20)				Insufficient	Data					10 PPI foam in standoff
20	(-,90,4,90,18,15)	3	3	14	2	37	35	6.1	0.57	2.13	10 PPI foam in tank
21	(-,90,9,90,0,20)	3	3		N/A						No standoff
22	(-,90,9B,90,0,15)				Insufficient	Data					9" standoff backside
23	(-,90,9B,90,23,15)				Insufficient	Data					9" standoff backside
24	(-,90,27B,90,0,15)				Insufficient	Data					27" standoff backside
25	(-,90,27B,90,7,15)	1	1	U	U	86	79	U	U	U	27" standoff backside
26	(-,90,27B,90,33,15)	0	1	U	U	U	316	U	U	U	27" standoff backside
27	(-,90,27,90,0,15)	3	2	4,789	7,688	139	72	1.6	0.97	2.35	
28	(-,90,27,90,7,15)	2	3	1,250	5,200	103	77	4.2	0.46	2.35	
29	(-,90,27H,90,0,15)	2	3	1,152	6,480	147	177	5.6	0.48	2.35	27" standoff with hat section
30	(-,90,27H,90,4,15)	3	3	252	7,783	92	114	30.9	0.43	2.13	27" standoff with hat section

*T_c = T value at 95.0% (10% error - two tail)

**Values showing a statistical difference

TABLE V

MAXIMUM STANDOFF PRESSURE RISE FOR JP-4 vs. JP-8 FUEL (psi x 10)

No.	Test Description a b c d e f	n		VARIANCE (σ^2)		MEAN ($\bar{X}$)		F Ratio	T	T_c *	REMARKS
		JP-4	JP-8	JP-4	JP-8	JP-4	JP-8				
1	(-,90,9,0,0,20)	4	5	18,244	2,569	229	108	7.1	1.88	1.90	
2	(-,90,9,90,0,20)	6	5	18,653	1,115	231	102	16.7	2.05**	1.83	
3	(-,90,9,90,23,20)	6	5	870	1,299	54	82	1.49	1.43	1.83	
4	(-,90,9,90,96,20)	6	4	369	455	61	67	1.23	0.46	1.85	
5	(-,90,9,300,101,20)	6	5	82	325	64	56	4.0	0.87	1.83	
6	(-,90,9,300,325,20)	6	3	9,856	1,185	129	201	8.3	1.20	1.90	
7	(-,90,4,0,0,20)	6	6	21,473	3,076	250	119	7.0	2.05**	1.81	
8	(-,90,4,90,0,20)	5	6	31,889	1,088	137	144	29.3	0.10	1.83	
9	(-,90,4,90,18,20)	6	5	306	190	40	52	1.6	1.29	1.83	
10	(-,90,4,90,75,20)	5	4	2,129	1,276	64	71	1.7	0.25	1.90	
11	(-,90,4,300,58,20)	4	4	71	156	45	61	2.2	2.13**	1.94	
12	(-,90,4,300,180,20)	4	4	2,613	1,748	77	54	1.5	0.72	1.94	
13	(-,90,1,0,0,20)	3	4	17	259	5	18	14.9	1.37	2.02	
14	(-,90,1,90,0,20)	4	4	4	268	9	24	73.0	1.82	1.94	
15	(-,75,9,90,23,20)	2	3	1,800	709	102	57	2.5	1.49	2.35	

TABLE V (CONTINUED)

No.	Test Description a b c d e f	n JP-4	n JP-8	VARIANCE (σ^2) JP-4	VARIANCE (σ^2) JP-8	MEAN ($\bar{X}$) JP-4	MEAN ($\bar{X}$) JP-8	F Ratio	T	T_c*	REMARKS
16	(-,90,9,90,23,15)	4	4	120	260	58	57	2.2	0.10	1.94	
17	(-,75,9,90,97,20)	3	3	201	516	73	96	2.6	1.51	2.13	
18	(-,90,9,90,97,15)	3	3	36	952	66	123	26.5	3.16**	2.13	
19	(-,90,4,90,18,20)	3	3	9	0	3	0	U	1.89	2.13	10 PPI foam in standoff
20	(-,90,4,90,18,15)	3	3	1	9	11	15	7.0	2.47**	2.13	10 PPI foam in tank
21	(-,90,0,90,0,20)	3	3		N/A					2.13	No standoff
22	(-,90,9B,90,0,15)	3	3	0	0	0	0	U	U	2.13	9" standoff backside
23	(-,90,9B,90,23,15)	3	3	0	33	0	3	U	1.00	2.13	9" standoff backside
24	(-,90,27B,90,0,15)	3	3	0	0	0	0	U	U	2.13	27" standoff backside
25	(-,90,27B,90,7,15)	3	2	1,412	26,912	24	116	19.1	1.02	2.35	27" standoff backside
26	(-,90,27B,90,33,15)	3	3	3	265	1	11	88.4	1.09	2.13	27"standoff backside
27	(-,90,27,90,0,15)	3	3	69	1,669	337	27	24.1	12.89**	2.13	
28	(-,90,27,90,7,15)	2	3	613	50	117	17	12.2	7.05**	2.35	
29	(-,90,27H,90,0,15)	3	3	73,625	1,460	271	114	53.8	0.96	2.13	27" standoff with hat section
30	(-,90,27H,90,4,15)	3	3	11,191	1,873	265	58	1.0	3.14**	2.13	27" standoff with hat section

*T_c = T value at 95.0% (10% error - two tail)

**Values showing a statistical difference

b. At high dry bay ACPM, no clear difference exists between the two fuels, although as ACPM increases, the burn times generally tend to increase for both fuels.

b. Incendiary Burn Time in Standoff (Table II)

It was not expected that incendiary burn time would be a function of fuel type. Although the statistical results show cases where it appears significant, the direction of significance was mixed. Under five test conditions the incendiary burn time was significantly longer for JP-4, and under five other test conditions it was significantly longer for JP-8. These mixed results were most likely due to our inability to read the film properly and determine the difference between incendiary burn and fuel fire. Moreover, out of the 10 test conditions where significant difference in the means is seen, as evidenced by the larger T value, 8 also show a significantly larger F value, which explains the mixed results as being due to the masking effect of the variance. In other words, the significant difference in the means is well within the variability seen in the two distributions. Thus, the difference in the means cannot prove that either JP-4 or JP-8 affected the incendiary burn time.

c. Initial External Fuel Spray Time (Table III)

This factor was the time for the fuel to be seen on the external surface of the test article, as determined from film analysis. This time would be expected to be a function of the fire in the dry bay. At the very low dry bay ACPM, the initial external fuel spray time was significantly longer for JP-8 than for JP-4. This agrees with a previous conclusion, which showed that the fire duration for JP-8 was significantly longer at very low dry bay ACPM. At high ACPM, the spray time was independent of fuel type, although it tended to decrease for both fuels as ACPM increased and standoff distance decreased.

d. Time to Maximum Standoff Pressure (Table IV)

It is possible that the time to maximum standoff pressure is dependent on fuel type. Three cases show significance, but an evaluation of all cases as a whole does not prove a dependence on fuel type.

Of the 3 anomalous cases, two have a significantly larger F ratio. This explains the fact that the significant difference shown by the T value is masked by the corresponding F value.

e. Maximum Standoff Pressure Rise (Table V)

The maximum pressure in the dry bay was of major interest in the test program for assessing the difference between the two fuels. Eight cases show significance; in five of these, the higher pressures were obtained with JP-4. Data for these cases are as follows:

CASE No.	Test Description	Mean psi	
		JP-4	JP-8
2	(-,90,9,90,0,20)	23.1	10.2
7	(-,90,4,0,0,20)	25.0	11.9
11	(-,90,4,300,58,20)	4.5	6.1
18	(-,90,9,90,97,15)	6.6	12.3
20	(-,90,[illegible],90,18,15)	1.1	1.5
27	(-,90,27,90,0,15)	33.7	2.7
28	(-,90,27,90,7,15)	11.7	1.7
30	(-,90,27H,90,4,15)	26.5	5.8

Case 20 may be eliminated because an overpressure of 1.5 psi should be within the capability of most aircraft structures. This case was a vapor shot with 10 PPI reticulated polyurethane foam in the fuel tank, and severe foam damage occurred during all three tests with JP-4; little foam damage occurred with JP-8. Of the remaining seven cases, JP-4 produced higher pressures in five, with a mean average overpressure of 18.7 psi, compared to 7.2 for JP-8

Unfortunately, several cases had relatively high F values, which weakens the conclusion that JP-4 gives a statistically significant higher standoff pressure rise. Further analysis is required to resolve this.

Table VI presents the statistical results for the standoff overpressure for various combinations of the test conditions: Case 31 is a comparison of the two fuels for all test conditions. Case 32 considers all "Standard Tests" (i.e., all tests with the standoff on the front side, which excludes Cases 19 thru 26). Cases 33 through 37 are a breakdown of Case 32 by size of standoff.

Case 31 (all tests) shows that JP-4 having a higher overpressure than JP-8 is a significant result. Case 32 (Standard Tests) shows a significantly higher mean overpressure for JP-4, with only a 2.5% error possible, due to experimental chance. The remaining cases of Table VI indicated that for JP-4 the overpressure increased as the volume of the dry bay increased. This trend was not observed for JP-8.

TABLE VI

MAXIMUM STANDOFF PRESSURE RISE FOR JP-4 vs. JP-8 FUEL (psi x 10)

No.	Test Description a b c d e f	n		VARIANCE (σ^2)		MEAN ($\bar{X}$)		F Ratio	T	T_c*	REMARKS
		JP-4	JP-8	JP-4	JP-8	JP-4	JP-8				
31	All Tests	126	112	13,780	5,590	99	73	2.47	1.99**	1.65	
32	Standard Tests only	105	91	14,395	5,424	118	85	2.65	2.25**	1.65	Sign. at 2.5% error
33	All 9" Standoff	55	42	9,094	7,996	113	104	1.14	.45	1.66	Front side only
34	All 4" Standoff	31	29	14,646	2,541	106	89	5.76	.69	1.67	Front side only
35	All 1" Standoff	8	8	16	234	6	21	14.6	2.64**	1.76	Front side only
36	All 27" Standoff	5	6	14,818	716	249	22	20.7	4.48**	1.83	Front side only
37	27" Standoff	6	6	35,939	2,285	268	86	15.7	2.28**	1.81	Hat section on front

*T_c = T value at 95.0% (10% error - two tail)

**Value shows statistical difference

SECTION V

ANALYSIS OF TEST RESULTS

1. TEMPERATURE EFFECT ON STANDOFF OVERPRESSURE

An initial fuel temperature of 90°F was selected as the baseline temperature for the test program. The selection of this temperature was a trade-off between the most probable operational fuel temperature, and a temperature easily controlled in a test program. It is easier to heat fuel above ambient temperature than to cool it. In addition, we felt that the severity of the reactions for JP-8 would be less at lower temperatures, and those from JP-4 would be greater. To assess the effects that initial fuel temperature could have on the test results, we conducted several tests with both fuels at 75°F. The results of these tests are given in Table VII. There is no clear statistical evidence of the effect of fuel temperature on standoff overpressure for either fuel, although JP-4 tended to produce higher overpressures at the lower temperature. No trend was observed with JP-8.

2. TANK PRESSURE EFFECT ON STANDOFF OVERPRESSURE

A baseline initial fuel tank pressure of 20 psia was used during the first half of the program, based on the operational consideration that the positive pressure in the fuel tanks of most aircraft is in the range of 1-1/2 to 15 psi. About halfway through the test program, several tests were conducted at 15 psia and the results were compared, as shown in Table VIII. There is a clear indication that the standoff overpressure is not dependent on initial tank pressure for JP-4. Case 45 was significant, showing the lower initial tank pressure for JP-8 produced the higher standoff overpressure; case 44, however, indicated the reverse, although not at a significant level. Some unique cross-coupling between initial pressure and dry bay ACPM for JP-8 may have produced this result, although the test data was too limited to come to a definite conclusion. From an overall assessment of Table VIII, we conclude that no dependence of standoff overpressure on initial tank pressure was actually proven for either fuel. The second half of the program, however, was conducted at an initial fuel tank pressure of 15 psia.

TABLE VII

TEMPERATURE EFFECT ON MAXIMUM STANDOFF PRESSURE RISE (psi x 10)

No.	Test Description a b c d e f	n		VARIANCE (σ^2)		MEAN ($\bar{X}$)		F Ratio	T	T_c**	REMARKS
		75°F	90°F	75°F	90°F	75°F	90°F				
38	(4,75,9,90,23,20) vs (4,90,9,90,23,20)	2	6	1800	870.4	102	54	2.07	1.84	1.94	
39	(4,75,9,90,96,20) vs (4,90,9,90,96,20)	3	6	201	369	73	61	1.83	0.92	1.90	
40	(8,75,9,90,23,20) vs (8,90,9,90,23,20)	3	5	709	1299	57	82	1.83	1.03	1.94	
41	(8,75,9,90,96,20) vs (8,90,9,90,96,20)	3	4	516	455	96	67	1.13	1.73	2.01	

*T_c = T value at 95.0% (10% error - two tail)

TABLE VIII

INITIAL TANK PRESSURE EFFECT ON MAXIMUM STANDOFF PRESSURE RISE (psi x 10)

No.	Test Description a b c d e f	n 15 psia	n 20 psia	VARIANCE (σ^2) 15 psia	VARIANCE (σ^2) 20 psia	MEAN ($\overline{X}$) 15 psia	MEAN ($\overline{X}$) 20 psia	F Ratio	T	T_c*	REMARKS
42	(4,90,9,90,23,15) vs. (4,90,9,90,23,20)	4	6	120	870	58	54	7.25	0.26	1.86	
43	(4,90,9,90,97,15) vs. (4,90,9,90,97,20)	3	6	36	369	66	6[illegible]	10.3	0.43	1.90	
44	(8,90,9,90,23,15) vs. (8,90,9,90,23,20)	4	5	260	1299	57	82	5.0	1.29	1.99	
45	(8,90,9,90,97,15) vs. (8,90,9,90,97,20)	3	4	952	455	123	67	2.09	2.88**	2.01	

*T_c = T value at 95.0% (10% error - two tail)

**Value shows statistical difference

3. EXTERNAL AIRFLOW EFFECT ON STANDOFF OVERPRESSURE

The amount of external airflow over the test article was not expected to affect the overpressure in the standoff. Eight cases (46 - 53) where direct comparisons could be made are shown in Table IX. The statistical results verify the expected results; however, the external airflow was expected to affect the degree and type of fire outside the test article. As noted in the Remarks, all sustained external fires occurred with no external airflow. A complete list of test conditions which produced sustained external fires is given below:

TEST DESCRIPTION	NO. OF SUSTAINED EXTERNAL FIRES
(4,90,9,90,0,20)	1
(4,90,9,0,0,20)	3
(4,90,4,90,75,20)	1
(4,90,1,0,0,20)	3
(4,100,1,0,0,20)	1
(4,90,0,90,0,20)-(no standoff)	2
(4,90,27,90,0,15)	1
(4,90,27,90,4,15)	1
(4,90,27,90,7,15)	2
(8,90,27,90,0,15)	2

Sustained external fires were defined as having a duration of two seconds or longer. In most cases beyond two seconds, it was impossible to determine whether the fire was being sustained by the fuel of the test article or the fuel on the pad. When a sustained fire was noted, it was standard test procedure to increase the external airflow to about 200 knots and wait 30 seconds, which extinguished the fire in about 50% of the cases. In the remaining cases, the Fire Department extinguished the fire after about 5 minutes elapsed time with zero airflow.

Out of a total of 34 tests with no external airflow, 7 resulted in sustained external fires; of 174 tests conducted with 90 knots external airflow, 10 sustained external fires; of 6 tests conducted at 125 knots and 38 tests conducted at 300 knots external airflow, none sustained external fires. From this we concluded that the probability of sustained external fires occurring outside the test article was reduced as external

TABLE IX

EXTERNAL AIR FLOW EFFECTS ON MAXIMUM STANDOFF PRESSURE RISE (psi x 10)

No.	Test Description a b c d e f	n		VARIANCE (σ^2)		MEAN ($\overline{X}$)		F Ratio	T	T_c^*	REMARKS
46	(4,90,9,0,0,20)	4		18244		229					2 S.E.F** at 0 knots
	vs.							1.02	0.02	1.86	0 S.E.F. at 90 knots
	(4,90,9,90,0,20)		6		18653		231				
47	(4,90,9,90,96,20)	6		369		61					0 S.E.F. at 90 knots
	vs.							4.5	0.31	1.81	0 S.E.F. at 300 knots
	(4,90,9,300,101,20)		6		82		64				
48	(4,90,4,0,0,20)	6		21473		250					0 S.E.F. at 0 knots
	vs.							1.49	1.16	1.83	0 S.E.F. at 90 knots
	(4,90,4,90,0,20)		5		31889		137				
49	(4,90,1,0,0,20)	3		17		5					3 S.E.F. at 0 knots
	vs.							4.7	1.66	2.01	
	(4,90,1,90,0,20)		4		4		9				0 S.E.F. at 90 knots
50	(8,90,9,0,0,20)	5		2569		108					0 S.E.F. at 0 knots
	vs.							2.3	0.21	1.86	
	(8,90,9,90,0,20)		5		1115		102				0 S.E.F. at 90 knots

TABLE IX (CONTINUED)

No.	Test Description a b c d e f	n		VARIANCE (σ^2)		MEAN ($\bar{X}$)		F Ratio	T	T_c*	REMARKS
51	(8,90,9,90,96,20)	4		455		67					0 S.E.F. at 90 knots
	vs.							1.4	0.81	1.90	
	(8,90,9,300,101,20)		5		325		56				0 S.E.F. at 300 knots
52	(8,90,4,0,0,20)	6		3076		119					0 S.E.F. at 0 knots
	vs.							2.8	0.94	1.81	
	(8,90,4,90,0,20)		6		1088		144				0 S.E.F. at 90 knots
53.	(8,90,1,0,0,20)	4		259		18					0 S.E.F. at 0 knots
	vs.							1.0	0.48	1.94	
	(8,90,1,90,0,20)		4		268		24				0 S.E.F. at 90 knots

*T_c = T value at 95.0% (10% error - two tail)

**S.E.F. Sustained External Fire

airflow increased. It should be noted that out of a total of 133 tests with JP-4 fuel, 15 sustained external fires, whereas out of 119 tests with JP-8, only 2 sustained external fires.

4. EFFECT OF VOID SPACE AIR CHANGES PER MINUTE ON STANDOFF OVERPRESSURE

The ACPM in the standoff was varied over a wide range of test conditions for both fuels. Results indicated the following.

For zero ACPM, the void space was essentially a sealed container. For the tests with a positive ACPM, the void space was modified to accept ram air from the external airflow and to dump the exit air overboard. Figures 5, 6, and 7 show the resulting void space overpressure as a function of ACPM for both JP-4 and JP-8 in four different test articles. The case numbers are shown for reference to test conditions presented previously. Some of the plotted points are a combination of cases, since the test conditions were similar except for the external airflow, and this, as indicated previously, had little effect on overpressure.

After reviewing these figures and considering the standard deviation (σ), we determined that the conditions for the tests listed in Table X should be analyzed for statistical significance. Based on the information of Table X, we noted the following:

a. For JP-4 in the 9 inch standoff, there was a large decrease in overpressure at moderate ACPM (23 to 100) compared to that at zero ACPM. No positive comparative statement can be made for the high ACPM (325).

b. For JP-8 in the 9 inch standoff, there was a small decrease in overpressure at moderate ACPM (~100) compared to that at zero ACPM. The maximum overpressure occurred at the high ACPM (325).

c. In the 4 inch standoff, both JP-4 and JP-8 experienced a decrease in overpressure at moderate ACPM (18 to 180) compared to that at zero ACPM.

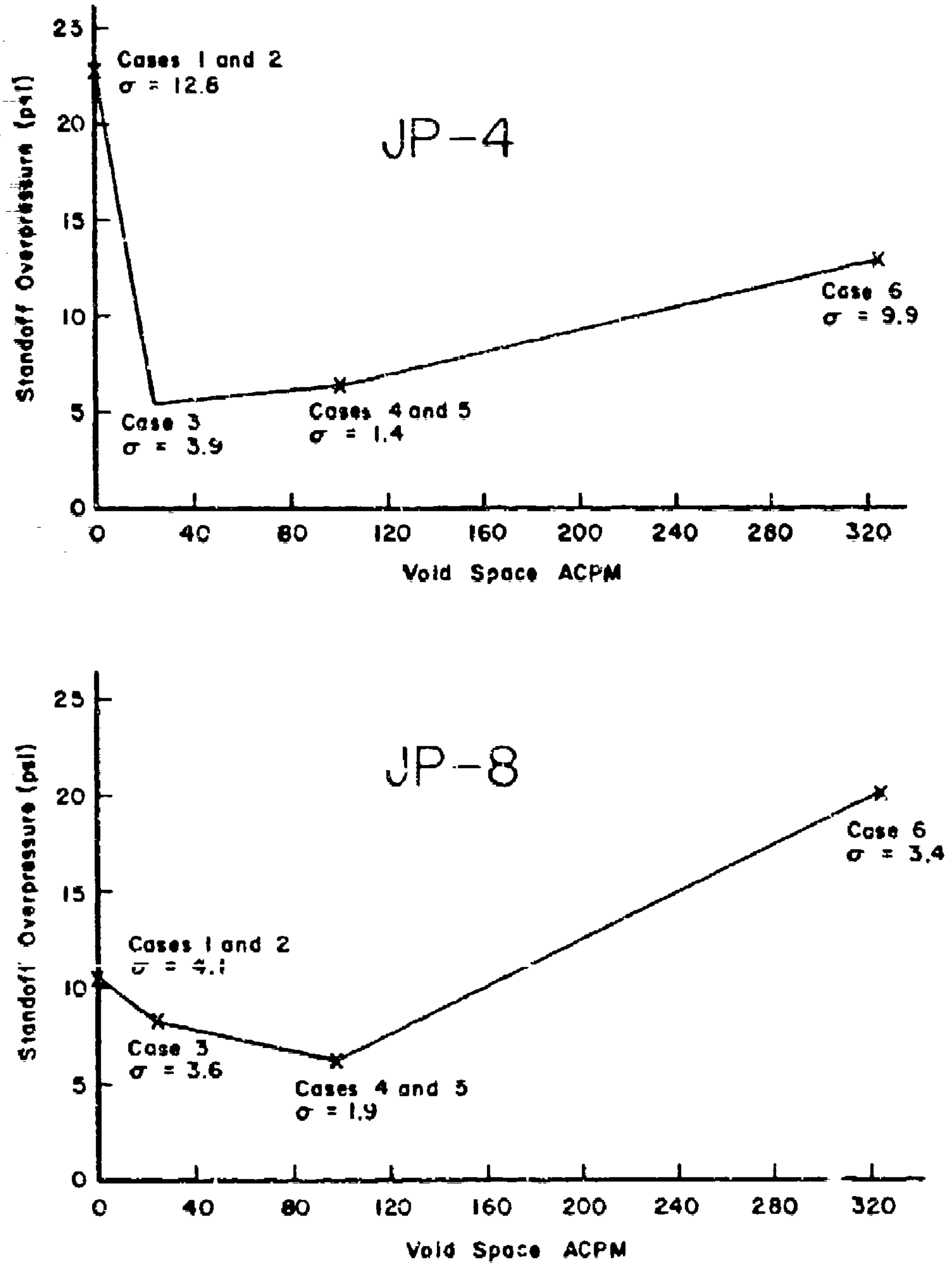


Figure 5. Overpressure vs. ACPM for JP-4 and JP-8 Fuels in 9-Inch Standoff

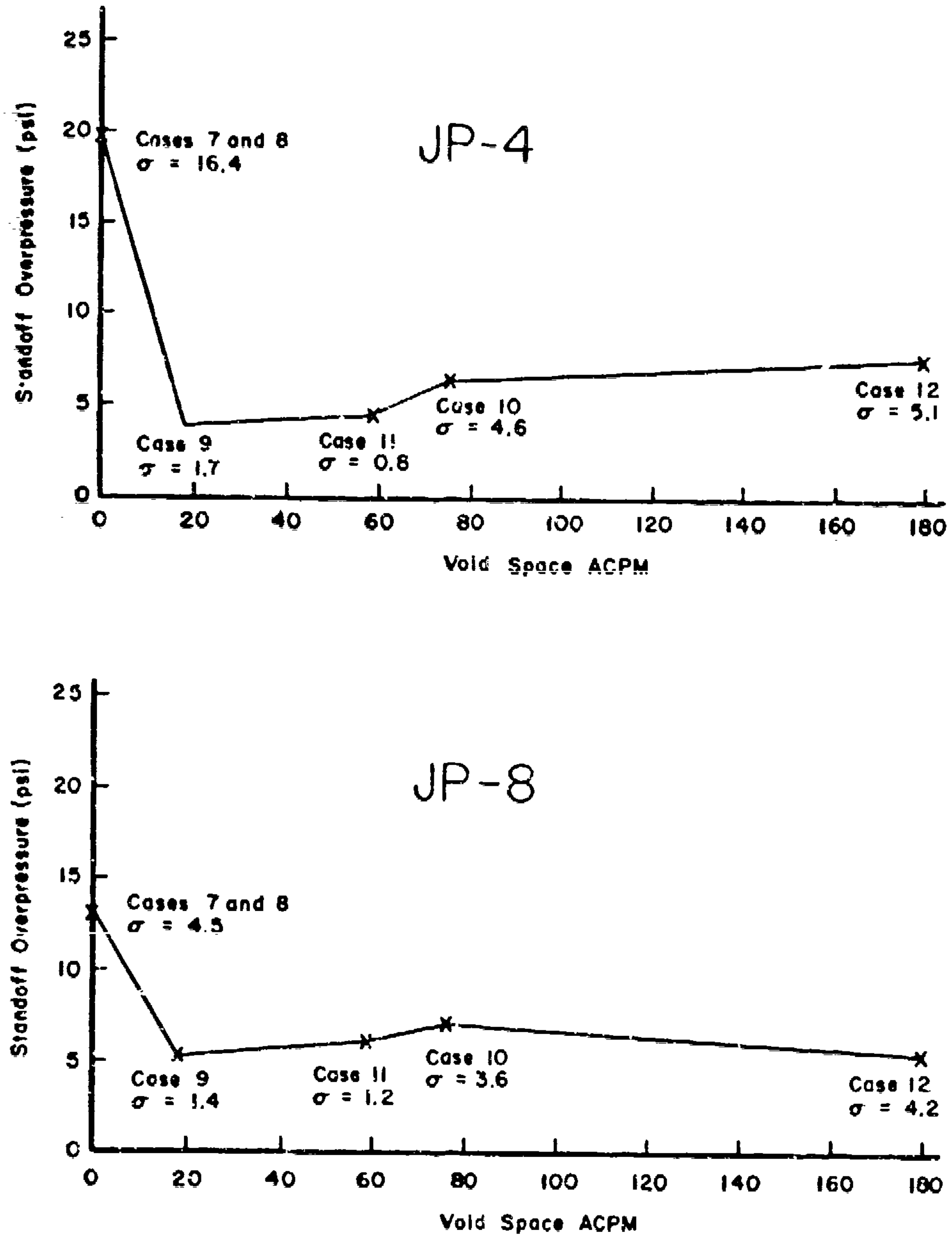


Figure 6. Overpressure vs. ACPM for JP-4 and JP-8 Fuels in 4-Inch Standoff

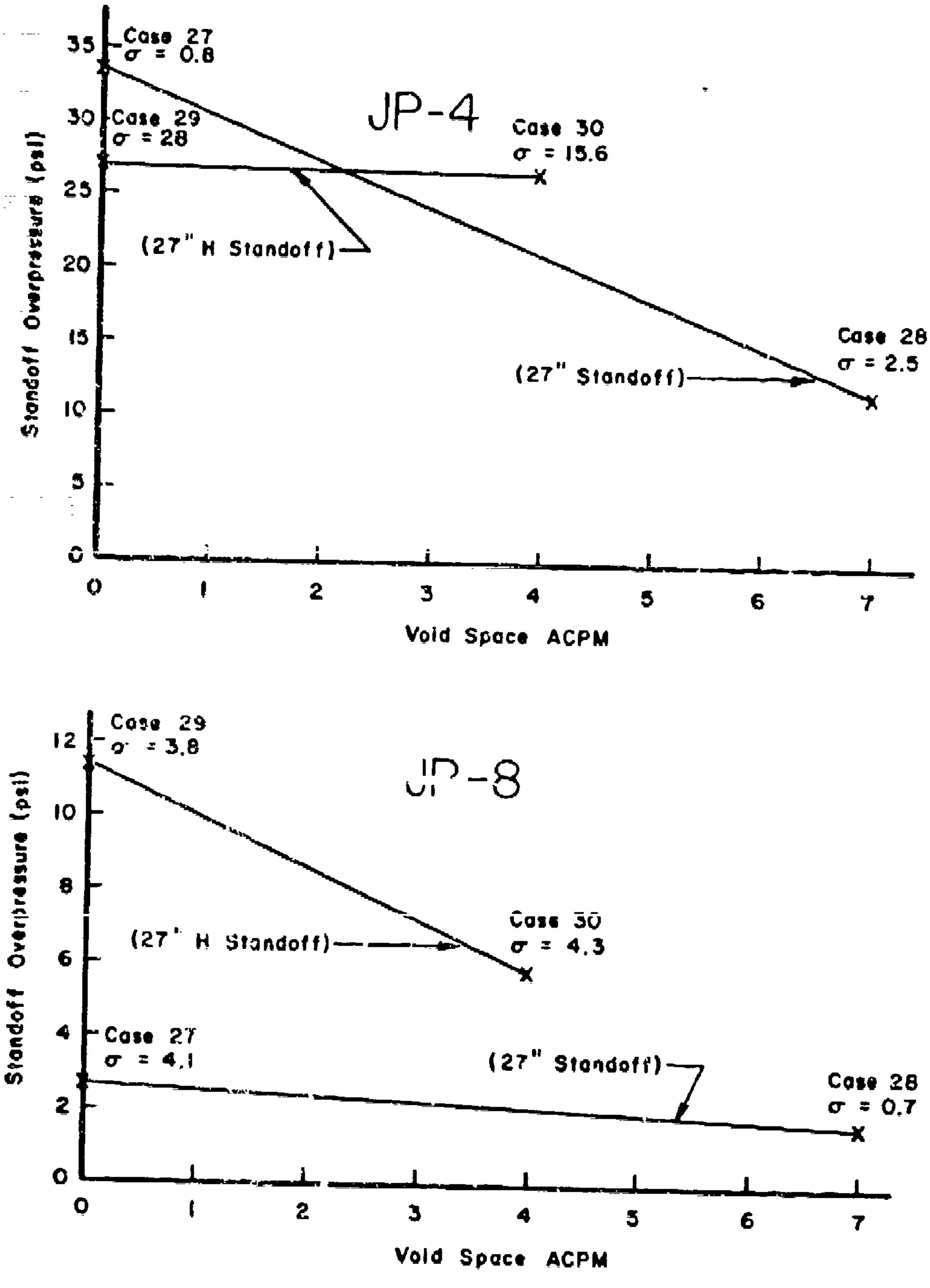


Figure 7. Overpressure vs. ACPM for JP-4 and JP-8 Fuels in 27-Inch and 27H Standoff

TABLE X

EFFECT OF ACPM ON MAXIMUM STANDOFF PRESSURE RISE
(psi x 10)

No.	Test Description	n		VARIANCE (σ^2)		MEAN ($\overline{X}$)		F Ratio	T	T_c*	REMARKS
54	JP4, Cases 1&2 vs 3	10	6	16446	870	231	54	18.9	3.28**	1.76	
55	JP4, Cases 1&2 vs 4&5	10	12	16446	207	231	62	79.4	4.53**	1.72	
56	JP4, Cases 1&2 vs 6	10	6	16446	9855	231	129	1.7	1.66	1.76	
57	JP8, Cases 1&2 vs 4&5	10	9	1649	364	105	61	4.5	2.96**	1.74	
58	JP8, Cases 1&2 vs 6	10	3	1646	1185	105	201	1.4	3.70**	1.80	
59	JP8, Cases 4&5 vs 6	9	3	364	1185	61	201	3.3	10.83**	1.81	
60	JP4, Cases 7&8 vs 9	11	6	26985	306	199	40	88.3	2.33**	1.75	
61	JP8, Cases 7&8 vs 9	12	5	2059	190	132	52	10.8	3.79**	1.75	
62	JP4, Case 27 vs 28	3	2	69	612	337	117	8.8	15.29**	2.35	
63	JP8, Case 29 vs 30	3	3	1460	1873	114	58	1.3	1.69	2.13	

*T_c = T value at 95.0% (10% error - two tail)

**Value shows statistical difference

d. In the 27 inch standoff, JP-4 experienced a large decrease in overpressure with small ACPM compared to that at zero ACPM, but in the 27 inch H Standoff experienced no difference between small ACPM and zero ACPM.

e. In the 27 inch and 27 inch H standoffs, JP-8 experienced no significant difference between zero ACPM and the small ACPM.

The foregoing statements apply to specific tank configurations and therefore are of little general value. We attempted to obtain more information by assuming that the amount of fuel entering the dry bay was to some degree independent of tank configuration, and that the volume of airflow in the dry bay determined the size of the flammability region and therefore the overpressure. Figure 8 gives the results of the effort and Table XI the statistical information. This analysis provided little additional insight, although it showed that at an airflow of 60 to 80 ft^3/min, JP-4 reached a peak of overpressure whereas JP-8 hit a minimum. These airflows should be considered in any additional testing to determine the effect of airflow on dry bay overpressure.

5. DAMAGE POTENTIAL

Considering standoff overpressure as the critical parameter for comparing the two fuels was predicated on potential damage to the aircraft structure and danger of implosion of a fuel tank. In general, fuel tanks are designed to withstand a higher internal than external overpressure. Figure 9 was developed for the "Standard Test Conditions" to show the probability of a given overpressure or greater occurring as a function of overpressure. As may be seen, the probability of JP-4 is higher than for JP-8, particularly in the range of 10 to 40 psi. This figure, however, does not tell the complete story; the first step in arriving at a Total Damage Potential term requires that the probability distribution for the standoff overpressure for each fuel be established. Figure 10 gives the probability distribution developed from a histrogram of the test data. By definition, the total probability must be unity, therefore the area for the two fuels must be equal.

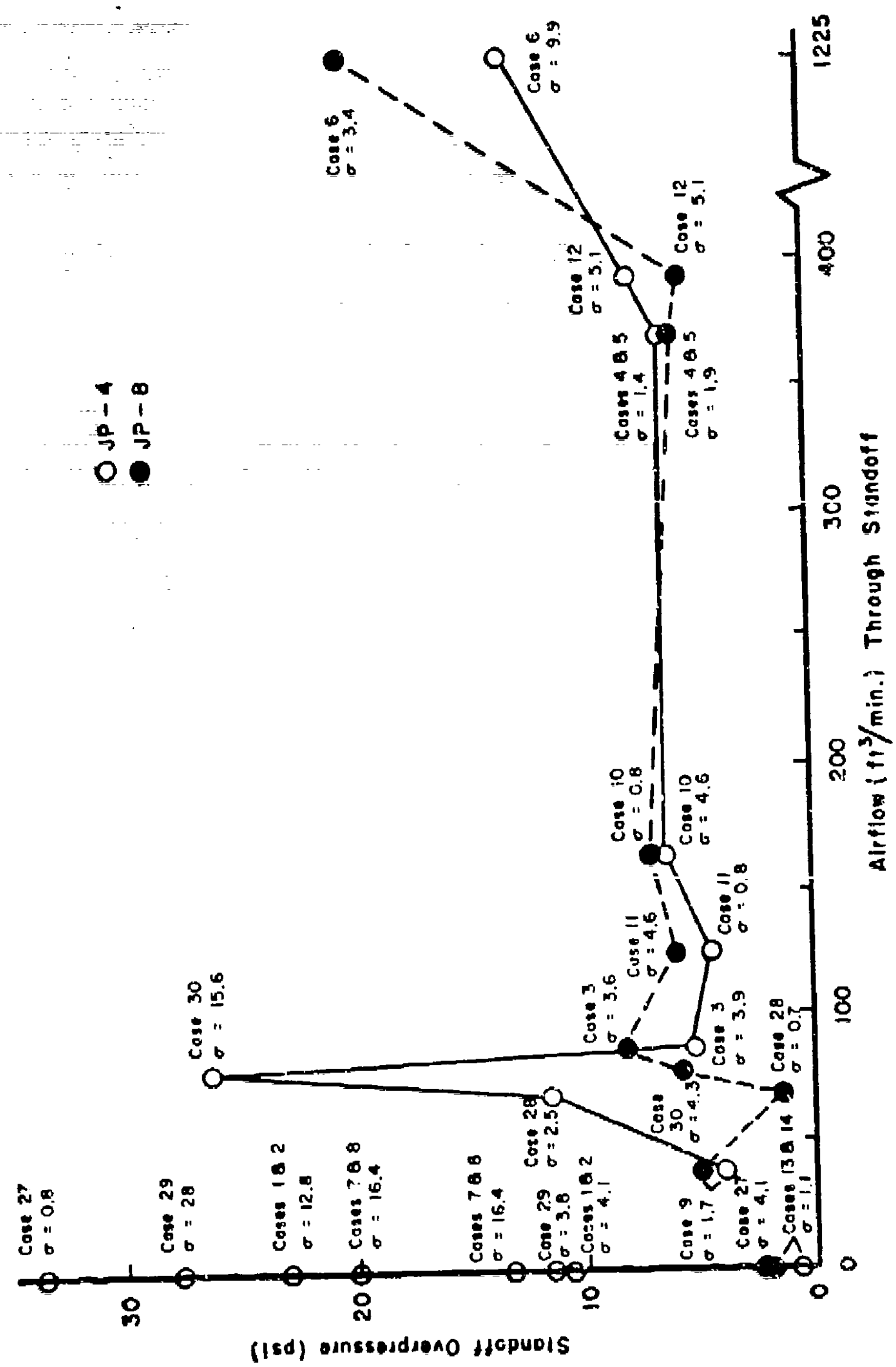


Figure 8. Overpressure vs. Air Flow in Standoff

TABLE XI

AIR FLOW EFFECT ON MAXIMUM STANDOFF PRESSURE RISE

No.	Test Description	n		VARIANCE (σ^2)		MEAN ($\bar{X}$)		F Ratio	T	T_c*	REMARKS
64	JP4, Cases 1&2 vs 7&8	10	11	16446	26985	231	199	1.6	0.47	1.73	
65	JP4, Cases 7&8 vs 13&14	11	7	26985	12	199	7	2285.	3.06**	1.75	
66	JP4, Cases 1&2 vs 27	10	3	16445	69	231	337	237.2	1.40	1.80	
67	JP4, Case 27 vs 29	3	3	69	78525	337	271	1134.	0.58	2.13	
68	JP4, Case 3 vs 9	6	6	870	306	54	40	2.9	1.04	1.81	
69	JP4, Case 9 vs 28	6	2	306	613	40	117	2.0	4.99**	1.94	
70	JP4, Case 28 vs 30	2	3	612	11191	117	256	18.3	1.86	2.35	
71	JP8, Cases 1&2 vs 7&8	10	12	1646	2059	105	132	1.3	1.44	1.72	
72	JP8, Cases 7&8 vs 13&14	12	8	2059	234	132	21	8.8	6.62**	1.74	
73	JP8, Cases 1&2 vs 27	10	3	1646	1669	105	27	1.0	3.41**	1.80	
74	JP8, Case 27 vs 29	3	3	1669	1460	27	114	1.1	3.82**	2.13	
75	JP8, Case 3 vs 9	5	5	1299	190	82	52	6.8	1.75	1.86	
76	JP8, Case 9 vs 28	5	3	190	50	52	17	3.8	3.96**	1.94	
77	JP8, Case 28 vs 30	3	3	1873	50	58	17	37.2	1.61	2.13	

*T_c = T value at 95.0% (10% error - two tail)

**Values show statistical difference

Since the force acting on a surface that tends to produce failure is proportional to the overpressure, a Damage Potential term ($DP_{\Delta P}$) may be defined for each overpressure. The point to be made here is that a high overpressure will result in more damage to the aircraft than a smaller overpressure. With this assumption, $DP_{\Delta P}$ was defined as $P_r \Delta P$, and the results are shown on Figure 11. A total Damage Potential may then be defined as a function of safe overpressure; the safe overpressure is dependent on the design of a particular tank and is defined as the pressure below which no damage occurs. The total Damage Potential (T D P) therefore is:

$$TDP = \sum_{\Delta P_{Safe}}^{\Delta P_{\omega}} DP_{\Delta P} \quad \text{or} \quad \sum_{\Delta P_{Safe}}^{\Delta P_{\infty}} P_r \, \Delta P$$

The results of this calculation are shown in Figure 12. JP-4 has a higher potential for damage than does JP-8, which was verified by the test article damage experienced during the test program.

The ratio of percentage of damage to the test article by JP-4 vs. that by JP-8, as given in Table XII, was 2.39. The ratio of area under the curves of Figure 12 for the two fuels was 2.45. The closeness of this comparison was somewhat surprising. Although there is no absolute measure for damage potential, these results should give a good relative measure for the two fuels.

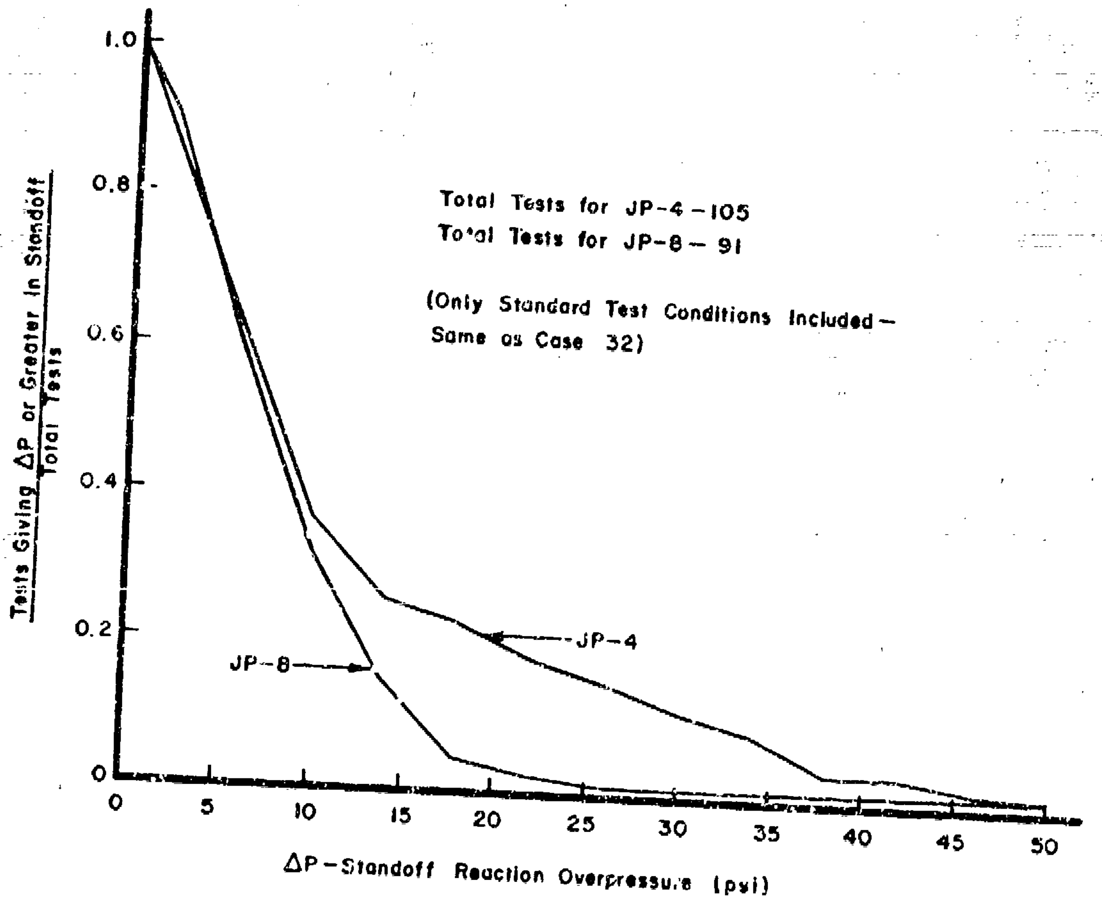


Figure 9. Probability of a Given Overpressure or Greater Occurring

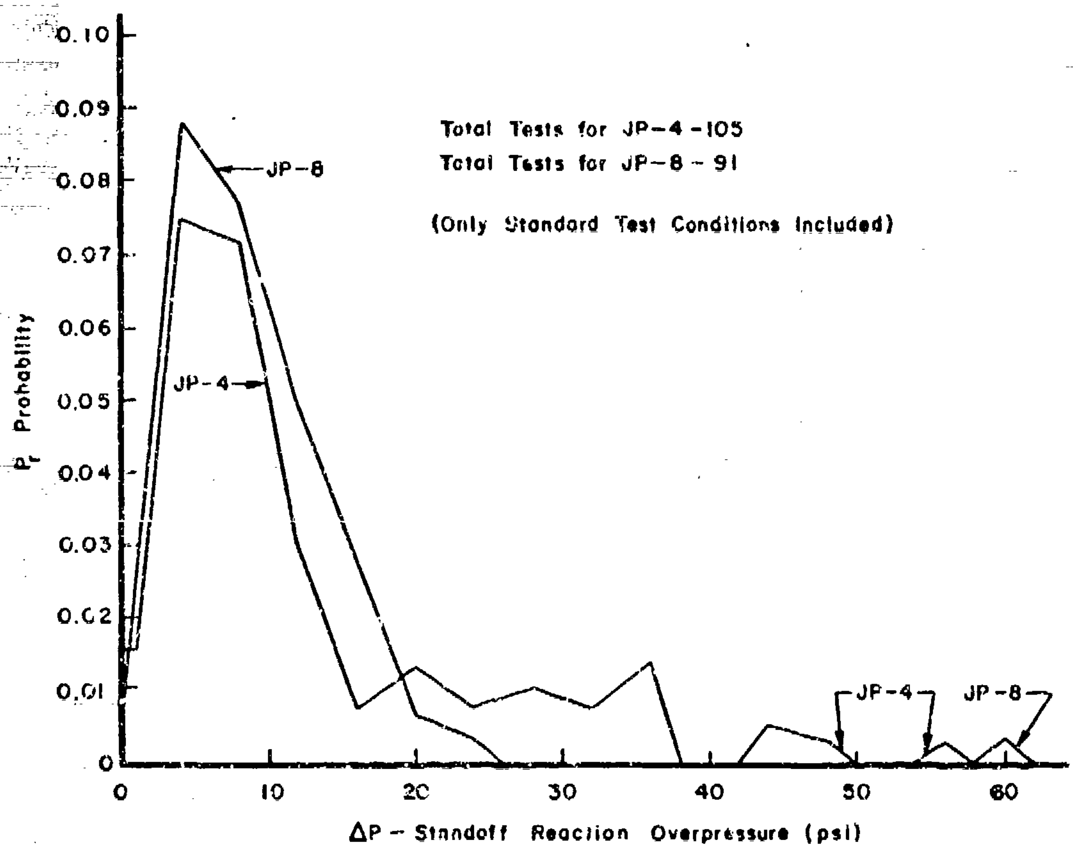


Figure 10. Probability Distribution for Standoff Overpressure

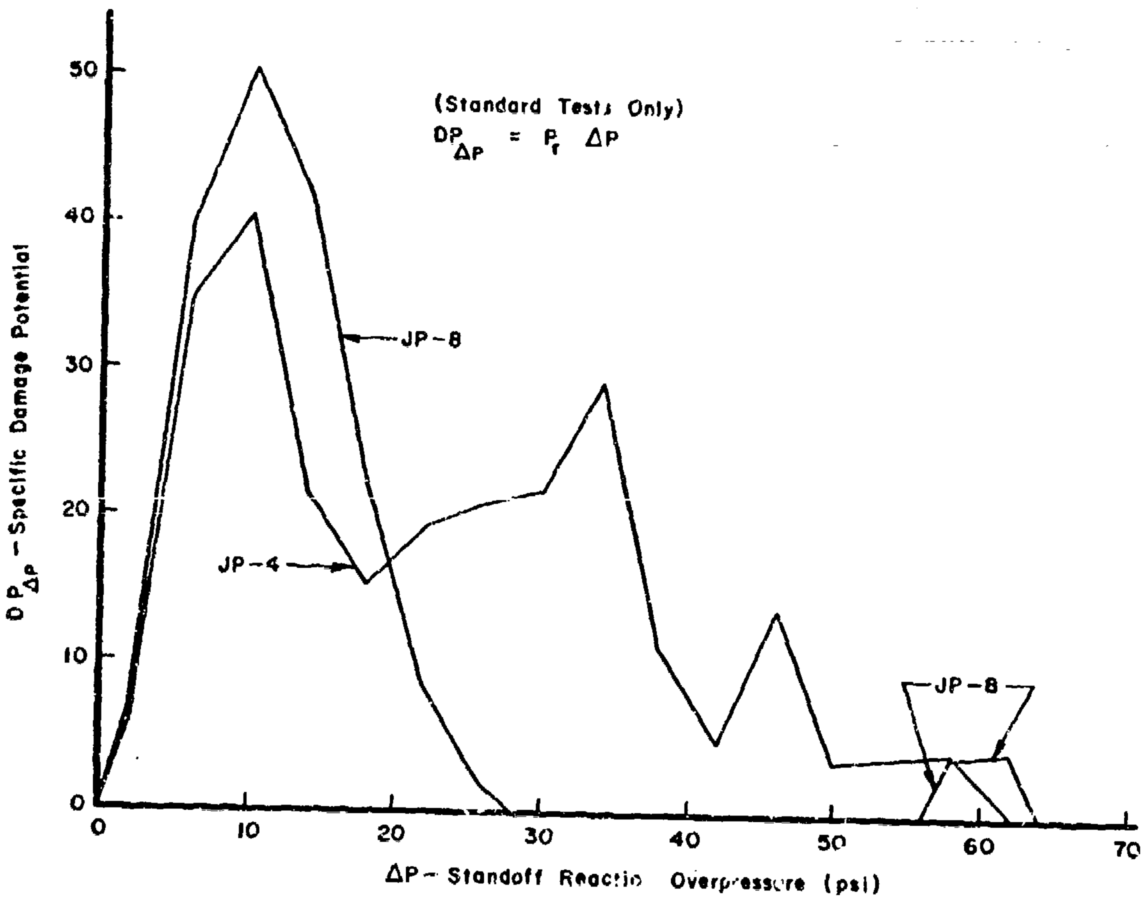


Figure 11. Specific Damage Potential for Each Standoff Overpressure

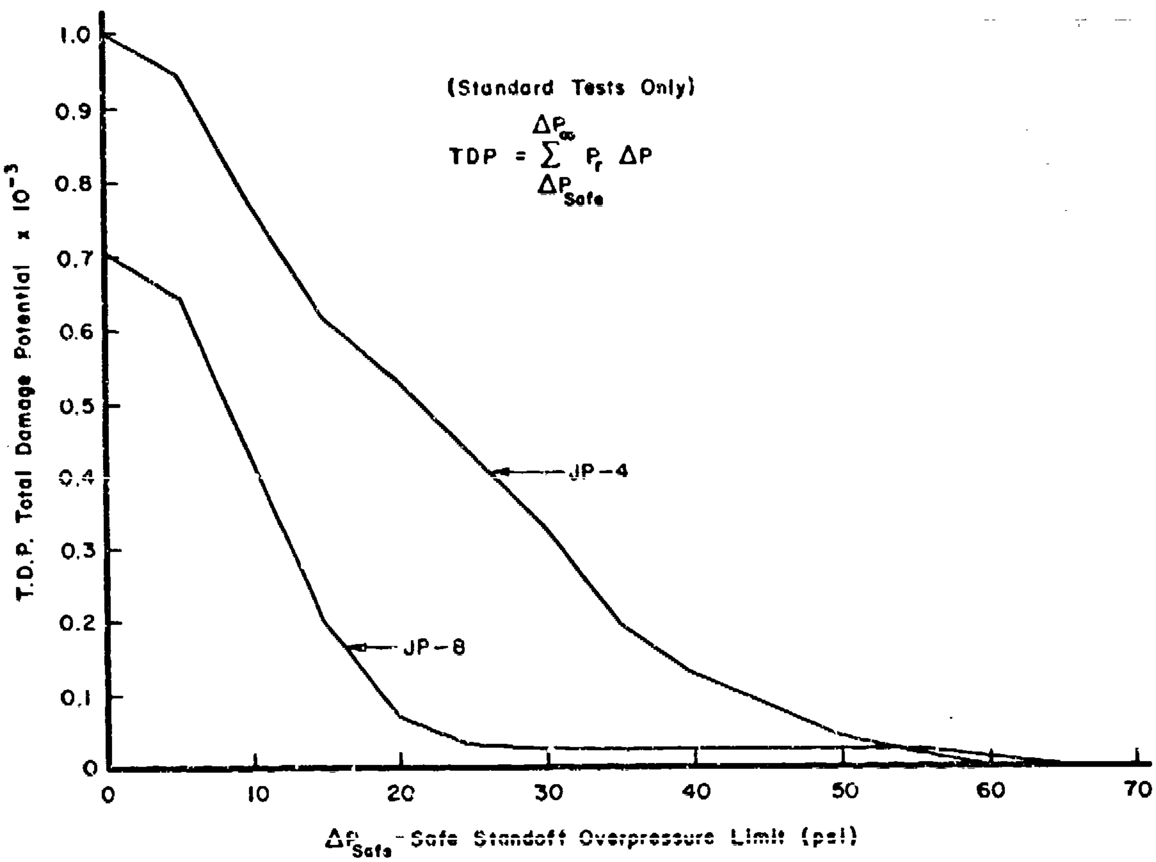


Figure 12. Total Damage Potential vs. Safe Standoff Overpressure Limit

6. OTHER FACTORS

Table XII summarizes results for factors not previously discussed. Of particular interest is that twice as many external flash fires occurred with JP-8 than with JP-4, whereas over six times as many sustained external fires occurred with JP-4.

Although all the test articles were constructed of heavy gauge steel and were designed for repeated gunfire testing, several failures did occur. There was a significantly larger number of tank failures associated with the JP-4 shots than with JP-8. These failures (16 with the JP-4 and 6 with JP-8) included blowing off the strike-plate, (which is equivalent to failure of the external skin of the aircraft), broken tank pressurization line, failure of the void space exhaust ventilation tube, and structural damage to the basic test article.

Another factor not discussed previously was the pressure rise in the fuel tank. No overpressure was observed for either fuel due to a fuel reaction inside the fuel tank; this was expected due to the design of the experimental program. This is not to say that no overpressures were measured in the fuel tank, but that the overpressures measured resulted from projectile dynamics and not from fuel reactions, as expected. The statistical results for the fuel tank overpressure are as follows:

	JP-4		JP-8
No. of Tests	105		89
Mean Overpressure (psi)	2.61		2.29
Variance (psi)	39.1		20.4
F ratio		1.91	
T value		0.40	

TABLE XII

SUMMATION OF RESULTS

	JP-8		JP-4	
	Test	%	Test	%
Total Number of Tests	119		133	
Tests With Unknown or Unrecorded External Fires	0	0.00	0	0.00
Tests That Result in No External Fire	102	85.71	110	82.71
Summation of Flash, And Flash And Pit Fires (Less Than 2 Seconds)	15	12.61	8	6.02
Summation of Sustained Fires, Delayed Fires, And Fires And Explosions	2	1.68	15	11.28
Tests That Resulted in External Fires				
Flash Fire (Less Than 2 Seconds)	15	12.61	8	6.02
Flash And Pit Fire	0	0.00	0	0.00
Delayed Fire	0	0.00	0	0.00
Fire And Explosion	0	0.00	0	0.00
Sustained Fire (Greater Than 2 Seconds)	2	1.68	15	11.28
Tests That Resulted in Internal Fires				
Unknown Internal Reaction	13	10.92	8	6.02
No Internal Reaction	17	14.29	18	13.53
Reaction In Fuel Tank Only	0	0.00	0	0.00
Reaction In The Entrance Standoff	83	69.75	105	78.95
Reaction In The Standoff + Fuel Tank	2	1.68	1	.75
Reaction In The Exit Standoff	4	3.36	1	.75
Reaction In The Exit Standoff + Fuel Tank	0	0.00	0	0.00
Test Article Damage	6	5.04	16	12.03

SECTION VI

CONCLUSIONS

1. At very low dry bay ACPM, the standoff fire duration was longer for JP-8 than for JP-4. There was no clear difference between the two fuels at high ACPM.

2. The incendiary burn time of the CAL .50 API was not affected by fuel type.

3. At very low dry bay ACPM, the time for the JP-8 fuel to be seen on the external surface of the test article was longer than for JP-4. At high ACPM the time was independent of fuel type.

4. The time to maximum standoff overpressure was independent of fuel type.

5. Thirty different sets of test conditions were evaluated for each fuel, and in 7 of these a significant difference occurred in the standoff overpressure between the two fuels. For these seven cases, JP-4 had a mean value of 18.7 psi as compared to 7.2 psi for JP-8.

6. For the "Standard Tests" (i.e., all tests with the standoff on the front side) JP-4 gave higher standoff overpressure than JP-8 at the 97.5% confidence level. The mean value was 11.8 psi for JP-4 and 8.5 psi for JP-8.

7. For the vapor shots with 10 ppi reticulated polyurethane foam in the fuel tank, severe foam damage occurred with all three JP-4 tests, whereas little damage occurred with the three JP-8 tests.

8. The effectiveness of 10 ppi reticulated polyurethane foam in the 4-inch standoff in preventing dry bay overpressure and fire was the same for both fuels.

9. The fire and dry bay overpressure conditions were more severe when the dry bay was located on the entrance side than on the exit side. This was true for both fuels. As the distance the projectile traveled in the fuel prior to impacting the exit dry bay increased, the amount of fire and overpressure decreased. During all tests in this program, maximum incendiary action occurred at initial projectile impact; therefore the vulnerability of exit dry bays requires additional investigation.

10. There was no clear statistical proof of the dependence of standoff overpressure on fuel temperature (75°F vs. 90°F) for either fuel, although a trend was indicated for JP-4 to produce higher overpressures at lower temperature.

11. No dependence of standoff overpressure on initial tank pressure (15 psia vs. 20 psia) was proven for either fuel.

12. Although some information was generated on the effect of dry bay ACPM on overpressure for specific test articles, no general conclusions were established.

13. An analysis of the standoff overpressures showed that, on the average, the damage potential of JP-4 was 2.45 times that of JP-8. Actual test article damage experience during the test program resulted in a value of 2.39.

14. Sustained external fires occurred in 11.28% of the tests with JP-4 and in only 1.68% for JP-8.

15. The general conclusion of this program was that JP-8 is less susceptible to fire and explosion induced by gunfire and structural damage should be less than that with JP-4. Many other factors, however, must be considered in the determination of the overall desirability of JP-8. A report on this subject is planned for the near future.

APPENDIX I

TEST RESULTS

The following codes were used in the test results given in this appendix.

CODE	DEFINITION
	TYPE OF TEST
2	STATIC TEST WITH AIR VELOCITY (FAA TEST)
	TYPE OF FUEL
400	JP4
800	JP8 (118 DEG FLASH)
	TANK TYPE
30	FAA TANK-30 GAL (27 IN. STANDOFF AT ENTRANCE)
31	FAA TANK-30 GAL (27 IN. STANDOFF AT EXIT)
32	FAA TANK-30 GAL (27 IN. STANDOFF AT ENTRANCE WITH 10 CU. FT. HAT SECTION)
80	FAA TANK-80 GAL (9 IN. STANDOFF AT ENTRANCE)
81	FAA TANK-80 GAL (9 IN. STANDOFF AT EXIT)
106	FAA TANK-106 GAL (4 IN. STANDOFF AT ENTRANCE)
130	FAA TANK-130 GAL (1 IN. STANDOFF AT ENTRANCE)
135	FAA TANK-135 GAL (NO DRY BAY)
	TRAJECTORY PHASES
11	VAPOR
22	LIQUID
	SECOND TEMPERATURE
	TYPE 2 TEST - AMBIENT AIR TEMPERATURE
	FUEL AND SECOND TEMPERATURE
*	INDICATES TEMPERATURE APPROXIMATE
	STRIKER PLATE TYPE
42	2024-T3 ALUMINUM
73	2024-T3 ALUMINUM + 10PPI EXTERNAL FOAM
	PROJECTILE TYPE
53	50 CAL. API
	PROJECTILE VELOCITY
*	INDICATES VELOCITY APPROXIMATE
	TANK FILLER
100	NONE
200	R.P. FOAM 10 PPI

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CODE	DEFINITION
	EXTERNAL FIRE TYPES (FIRE TYPE)
1	NO FIRE
2	FLASH FIRE (LESS THAN 2 SECONDS)
3	SUSTAINED FIRE
4	DELAYED FIRE
5	FLASH AND PIT FIRE
6	FIRE AND EXPLOSION
7	UNKNOWN REACTION
	INITIAL TANK PRESSURE (PSIA)
-1	INDICATES UNKNOWN INITIAL TANK PRESSURE
	MAIN TANK PRESSURE RISE (PSI)
-1	INDICATES UNKNOWN PRESSURE RISE
	TIME TO MAXIMUM PRESSURE RISE MAIN TANK (SECONDS x 100)
	INDICATES UNKNOWN TIME TO MAXIMUM PRESSURE RISE
	INTERNAL REACTION (INT REA)
1	UNKNOWN REACTION
2	NO REACTION
3	FUEL TANK REACTION
4	ENTRANCE STANDOFF REACTION
5	ENTRANCE STANDOFF & FUEL TANK REACTION
6	EXIT STANDOFF REACTION
7	EXIT STANDOFF & FUEL TANK REACTION
8	LARGE SUSTAINED FIRE (GREATER THAN 2 SECONDS)
	CRITERIA I
-1	INDICATES UNKNOWN CRITERIA VALUE
	INCENDIARY FUNCTION
1	STANDOFF (YES) TANK (YES) EXTERNAL (YES)
2	STANDOFF (YES) TANK (YES) EXTERNAL (NO)
3	STANDOFF (YES) TANK (NO) EXTERNAL (YES)
4	STANDOFF (YES) TANK (NO) EXTERNAL (NO)
5	STANDOFF (NO) TANK (NO) EXTERNAL (NO)
6	STANDOFF (NO) TANK (NO) EXTERNAL (YES)
7	STANDOFF (NO) TANK (YES) EXTERNAL (NO)
8	STANDOFF (NO) TANK (YES) EXTERNAL (YES)
9	NO STANDOFF TANK (NO) EXTERNAL (YES)
	SPECIAL TEST CONDITIONS
2	STATIC TEST WITH AIR FLOW
	ULLAGE ATMOSPHERE
21	NORMAL AIR
	CRITERIA II
-1	INDICATES UNKNOWN CRITERIA VALUE
	STANDOFF FIRE DURATION (MILLISECONDS)

CODE	DEFINITION
	CRITERIA III
-1	INDICATES UNKNOWN CRITERIA VALUE
	INCENDIARY BURN TIME (MILLISECONDS)
	CRITERIA IV
-1	INDICATES UNKNOWN CRITERIA VALUE
	INITIAL EXTERNAL FUEL SPRAY TIME (MILLISECONDS)
-3	NO INITIAL EXT. FUEL SPRAY
	CRITERIA V
-1	INDICATES UNKNOWN CRITERIA VALUE
	TIME TO MAXIMUM STANDOFF PRESSURE RISE (MILLISECONDS)
	CRITERIA VI
-1	INDICATES UNKNOWN CRITERIA VALUE
	MAXIMUM STANDOFF PRESSURE RISE (PSI x 10)
	CRITERIA VII
-1	INDICATES UNKNOWN CRITERIA VALUE
	SECONDARY STANDOFF PRESSURE RISE (PSI x 10)
	CRITERIA VIII
-1	INDICATES UNKNOWN CRITERIA VALUE
	TIME TO SECONDARY STANDOFF PRESSURE RISE (MILLISECONDS)
	CRITERIA IX
-1	INDICATES UNKNOWN CRITERIA VALUE
	VOID SPACE AIR CHANGES (CHANGES/MIN)
	CRITERIA X
-1	INDICATES UNKNOWN CRITERIA VALUE
	AIR VELOCITY (FT/SECOND)

TEST CONDITIONS AND RESULTS

02/15/72

TEST NO	TYPE TEST	FUEL TYPE	TANK TYPE	FUEL VOL (GAL)	TRAJ PHASE	TEMP FUEL (DEG F)	TEMP AMB (DEG F)	(STRIKER (TYPE	THICK (IN)	-- PLATE SPACE (IN)	) ANGLE (DEG)	(PROJECTILE) (TYPE	(VEL) (FPS)	FILL TYPE	FIRE TYPE	TANK PRES (PSIA)	PRESS RISE (PSI)	TIME MAX P (S*100)	INT REA	CRIT I	* SEE DATA SHEET
TEST NO	SPEC TEST	CRIT II	ULL ATMO		CRIT III	CRIT IV	CRIT V	(VIBRATION) (FREQ) (CPM)	AMP) (IN)	(SLOSH (FREQ) (CPM)	AMP) (DEG)	CRIT VI	CRIT VII	CRIT VIII		FUEL DEPTH (IN)		CRIT IX		CRIT X	
1	2	400	80	60.0	22	30	32	42	.190	0.03	30	53	2400*	100	3	20.0	-1.0	-1	4	3	*
1	2	-1	21		14	19	-1					-1	0	0		18.0		0		0	
* STRIKER PLATE BLOWN OFF																					
2	2	400	80	60.0	22	45	45	42	.190	0.03	30	53	2400*	100	1	20.0	0.0	-1	4	1	
2	2	15	21		6	57	-1					-1	C	0		18.0		0		0	
3	2	400	80	60.0	22	98	97	42	.190	0.03	30	53	2400*	100	3	20.0	0.0	-1	4	3	*
3	2	-1	21		12	17	20					357	0	0		18.0		0		0	
* STRIKER PLATE FAILURE																					
4	2	400	80	60.0	22	90	91	42	.190	0.03	30	53	2400*	100	3	20.0	0.0	-1	4	3	
4	2	67	21		4	-1	8					39	0	0		18.0		0		0	
5	2	400	80	60.0	22	97	77	42	.190	0.03	30	53	2400*	100	[illegible]	20.0	2.2	-1	4	3	
5	2	130	21		2	215	151					272	0	0		18.0		0		0	
6	2	400	80	60.0	22	87	82	42	.190	0.03	30	53	2400*	100	1	20.0	2.6	-1	4	3	
6	2	71	21		6	192	54					249	0	0		18.0		0		0	
7	2	400	80	60.0	22	87	86	42	.190	0.00	30	53	2400*	100	1	20.0	.9	-1	4	3	
7	2	22	21		6	130	25					61	0	0		18.0		0		152	
8	2	400	80	60.0	22	71	78*	42	.215	0.03	30	53	2400*	100	1	20.0	3.0	-1	4	3	
8	2	156	21		11	066	89					183	0	0		18.0		0		152	
9	2	400	80	60.0	22	72	78*	42	.215	0.00	30	53	2400*	100	1	20.0	3.8	-1	4	3	*
9	2	-1	21		21	-1	109					115	C	0		18.0		0		152	
* LOST PRESSURE ON FUEL-AIR LINE (CONNECTION BROKE)																					
10	2	400	80	60.0	22	92	77*	42	.215	0.00	30	53	2400*	100	1	20.0	2.2	-1	4	3	
10	2	59	21		22	308	54					315	0	0		18.0		0		152	

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02/16/72

TEST NO	TYPE TEST	FUEL TYPE	TANK TYPE	FUEL VOL (GAL)	TRAJ PHASE	TEMP FUEL (DEG F)	TEMP AMB (DEG F)	(STRIKER (TYPE	THICK (IN)	-- PLATE) SPACE (IN)	ANGLE (DEG)	(PROJECTILE) (TYPE	VEL (FPS)	FILL TYPE	FIRE TYPE	TANK PRES (PSIA)	PRESS RISE (PSI)	TIME MAX P (S*100)	INT REA	CRIT I	* SEE DATA SHEET
TEST NO	SPEC TEST	CRIT II	ULL ATMO		CRIT III	CRIT IV	CRIT V	(VIBRATION) (FREQ (CPM)	AMP) (IN)	(SLOSH) (FREQ (CPM)	AMP) (DEG)	CRIT VI	CRIT VII	CRIT VIII		FUEL DEPTH (IN)		CRIT IX		CRIT X	
11	2	400	80	60.0	22	90	79*	42	.215	0.00	30	53	2400*	100	2	20.0	2.4	-1	4	3	
11	2	162	21		55	870	39					287	0	0		18.0		0		152	
12	2	400	80	60.0	22	91	72*	42	.215	0.00	30	53	2400*	100	[illegible]	20.0	0.0	-1	4	3	*
12	2	46	21		14	30	16					427	0	0		18.0		0		152	
* STRIKER PLATE FAILURE																					
13	2	400	80	60.0	22	92	77*	42	.215	0.00	30	53	2400*	100	1	20.0	3.2	-1	4	3	
13	2	92+	21		7	1142	96					167	0	0		18.0		0		0	
14	2	400	80	60.0	22	92	76*	42	.215	0.00	30	53	2400*	100	1	15.0	3.8	-1	4	3	*
14	2	592+	21		18	1420	110					587	0	0		18.0		0		0	
* NO 5PSI INITIAL PRESSURE IN TANK																					
15	2	400	80	60.0	22	94	82*	42	.215	0.00	30	53	2400*	100	1	20.0	2.8	-1	4	3	
15	2	519	21		15	1330	76					115	0	0		18.0		0		0	
15	2	400	80	60.0	22	96	85*	42	.215	0.00	30	53	2400*	100	1	20.0	2.2	-1	4	3	
16	2	534+	21		68	1328	92					108	0	0		18.0		0		0	
17	2	400	80	60.0	22	95	85*	42	.215	0.00	30	53	2400*	100	1	20.0	3.0	-1	4	3	
17	2	405	21		15	1212	142					121	0	0		18.0		0		0	
18	2	400	50	60.0	22	85	77*	42	.215	0.00	30	53	2400*	100	1	20.0	0.0	-1	2	3	
18	2	0	21		8	150	27					27	0	0		18.0		0		0	
19	2	400	80	60.0	22	84	69	42	.215	0.00	30	53	2400*	100	1	20.0	4.2	-1	4	3	
19	2	531	21		28	860	74					112	0	0		18.0		0		210	
20	2	400	80	60.0	22	80	67*	42	.215	0.00	30	53	2400*	100	1	20.0	3.6	-1	4	3	
20	2	199	21		54	718	45					219	0	0		18.0		0		210	

12/15/72

TEST NO / TEST NO	TYPE TEST / SPEC TEST	FUEL TYPE / CRIT II	TANK TYPE / ULL ATMO	FUEL VOL (GAL)	TRAJ PHASE / CRIT III	TEMP FUEL (DEG F) / CRIT IV	TEMP AMB (DEG F) / CRIT V	(STRIKER (TYPE / (VIBRATION) (FREQ) (CPM)	THICK (IN) / AMP) (IN)	-- PLATE) SPACE (IN) / (SLOSH) (FREQ) (CPM)	ANGLE) (DEG) / AMP) (DEG)	(PROJECTILE) (TYPE / CRIT VI	VEL) (FPS) / CRIT VII	FILL TYPE / CRIT VIII	FIRE TYPE	TANK PRES (PSIA) / FUEL DEPTH (IN)	PRESS RISE (PSI)	TIME MAX P (S*100) / CRIT IX	INT REA	CRIT I / CRIT X	* SEE DATA SHEET
21	2	400	80	60.0	22	86	77*	42	.215	9.00	30	53	2400*	100	1	15.0	3.4	-1	4	3	
21	2	521	21		22	202	68					109	0	0		18.0		0		210	
22	2	400	80	60.0	22	86	77*	42	.215	9.00	30	53	2400*	100	1	20.0	2.4	-1	4	3	
22	2	138	21		54	742	28					315	0	0		18.0		0		210	
23	2	400	80	60.0	22	90	69*	42	.215	9.00	30	53	2400*	100	1	20.0	2.2	-1	4	3	
23	2	399	21		42	778	69					112	0	0		18.0		0		210	
24	2	400	80	60.0	22	80	75*	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
24	2	59	21		82	470	-1					9	0	0		18.0		0		210	
25	2	800	80	60.0	22	86	64*	42	.215	9.00	30	53	2400*	100	1	20.0	1.0	-1	4	3	
25	2	548	21		80	100	54					87	0	0		18.0		0		152	
26	2	830	80	60.0	22	85	64*	42	.215	9.00	30	53	2400*	100	1	20.0	1.6	-1	4	3	
26	2	492	21		57	610	65					127	0	0		18.0		0		152	
27	2	800	80	60.0	22	85	72*	42	.215	9.00	30	53	2400*	100	1	20.0	31.6	47	5	3	
27	2	342	21		31	372	111					93	0	0		18.0		0		152	
28	2	800	80	60.0	22	92	77*	42	.215	9.00	30	53	2400*	100	1	20.0	4.2	-1	5	3	
28	2	335	21		32	768	100					60	0	0		18.0		0		152	
29	2	800	80	60.0	22	92	77*	42	.215	9.00	30	53	2400*	100	1	20.0	2.6	-1	4	3	
29	2	444	21		62	820	56					144	0	0		18.0		0		152	
30	2	800	80	60.0	22	72	65	42	.215	9.00	30	53	2400*	100	1	20.0	2.0	-1	4	3	
30	2	494	21		30	984	89					113	0	0		18.0		0		152	

02/16/72

TEST NO	TYPE TEST	FUEL TYPE	TANK TYPE	FUEL VOL (GAL)	TRAJ PHASE	TEMP FUEL (DEG F)	TEMP TNO (DEG F)	(STRIKER (TYPE	THICK (IN)	-- PLATE) SPACE (IN)	ANGLE (DEG)	(PROJECTILE) (TYPE	VEL) (FPS)	FILL TYPE	FIRE TYPE	TANK PRES (PSIA)	PRESS RISE (PSI)	TIME MAX P (S*100)	INT REA	CRIT I	* SEE DATA SHEET
TEST NO	SPEC TEST	CRIT II	ULL ATMO		CRIT III	CRIT IV	CRIT V	(VIBRATION) (FREQ (CPM)	AMP) (IN)	(SLOSH) (FREQ (CPM)	AMP) (DEG)	CRIT VI	CRIT VII	CRIT VIII		FUEL DEPTH (IN)		CRIT IX		CRIT X	
31	2	400	106	80.0	22	95	55	42	.215	4.00	30	53	2400*	100	2	20.0	1.4	-1	4	3	*
31	2	10	21		10	28	14					498	0	0		18.0		0		0	
* TANK PLATE BETWEEN STANDOFF AND FUEL DAMAGED																					
32	2	400	106	80.0	22	95	34*	42	.215	4.00	30	53	2400*	100	1	20.0	1.8	-1	4	3	
32	2	394	21		44	298	23					211	0	0		18.0		0		0	
33	2	400	106	80.0	22	85	50	42	.215	4.00	30	53	2400*	100	1	20.0	2.0	-1	4	3	
33	2	454 +	21		26	94	41					129	0	0		18.0		0		0	
34	2	400	106	80.0	22	85	51	42	.215	4.00	30	53	2400*	100	1	20.0	2.2	-1	4	3	
34	2	193	21		18	594	27					193	0	0		18.0		0		0	
35	2	400	106	80.0	22	95	55	42	.215	4.00	30	53	2400*	100	1	20.0	1.4	-1	4	3	
35	2	132	21		32	520	27					117	0	0		18.0		0		0	
36	2	400	106	80.0	22	35	57	42	.215	4.00	30	53	2400*	100	1	20.0	2.0	-1	4	3	
36	2	66	21		37	322	30					347	0	0		18.0		0		0	
37	2	400	106	80.0	22	90	53*	42	.215	4.00	30	53	2400*	100	1	20.0	1.6	-1	4	3	
37	2	91	21		25	144	21					21	0	0		15.0		0		152	
38	2	400	106	80.0	22	30	46*	42	.215	4.00	30	53	2400*	100	1	15.0	1.1	-1	4	3	*
38	2	16	21		*	[illegible]	*					150	0	0		18.0		0		152	
* WELD CRACKED AT BOTTOM OF TANK, PROBABLY WEAKED BY PRESSURE RISE IN TEST 37																					
39	2	400	106	80.0	22	90	33*	42	.215	4.00	30	53	2400*	100	1	20.0	2.8	-1	4	3	
39	2	175	21		31	606	18					238	0	0		18.0		0		152	
40	2	400	106	80.0	22	90	33*	42	.215	4.00	30	53	2400*	100	1	20.0	1.6	-1	4	3	
40	2	78	21		26	314	21					420	0	0		18.0		0		152	

02/16/72

TEST NO	TYPE TEST	FUEL TYPE	TANK TYPE	FUEL VOL (GAL)	PROJ PHASE	TEMP FUEL (DEG F)	TEMP TWO (DEG F)	(STRIKER TYPE	THICK (IN)	-- PLATE SPACE (IN)	ANGLE (DEG))	(PROJECTILE TYPE	VEL) (FPS)	FILL TYPE	FIRE TYPE	TANK PRES (PSIA)	PRESS RISE (PSI)	TIME MAX P (S*100)	INT REA	CRIT I	* SEE DATA SHEET
TEST NO	SPEC TEST	CRIT II	ULL ATMO		CRIT III	CRIT IV	CRIT V	(VIBRATION FREQ (CPM)	AMP) (IN)	(SLOSH FREQ (CPM)	AMP (DEG))	CRIT VI	CRIT VII	CRIT VIII		FUEL DEPTH (IN)		CRIT IX		CRIT X	
41	2	930	106	80.0	22	90	33*	42	.215	4.00	30	53	2400*	100	1	20.0	.8	-1	4	3	
41	2	0	21		6	172	-1					0	0	0		18.0		0		152	
42	2	430	106	80.0	22	90	33*	42	.215	4.00	30	53	2400*	100	1	20.0	.9	-1	4	3	
42	2	32	21		10	48	-1					36	0	0		19.0		0		152	
43	2	900	106	80.0	22	90	30*	42	.215	4.00	30	53	2400*	100	2	20.0	1.6	-1	4	3	
43	2	441*	21		22	74	-1					44	0	0		19.0		0		0	
44	2	930	106	80.0	22	90	35*	42	.215	4.00	30	53	2400*	100	2	20.0	1.9	-1	4	3	
44	2	455	21		10	976	10					159	0	0		18.0		0		0	
45	2	900	106	80.0	22	90	35*	42	.215	4.00	30	53	2400*	100	1	20.0	2.0	-1	4	3	
45	2	297	21		12	[illegible]	51					195	0	0		18.0		0		0	
46	2	900	106	80.0	22	90	42*	42	.215	4.00	30	53	2400*	100	1	20.0	1.7	-1	4	3	
46	2	359	21		8	863	200					105	0	0		18.0		0		0	
47	2	930	106	80.0	22	90	47*	42	.215	4.00	30	53	2400*	100	1	20.0	1.9	-1	4	3	
47	2	436	21		8	974	74					136	0	0		18.0		0		0	
48	2	930	106	80.0	22	90	42*	42	.215	4.00	30	53	2400*	100	1	20.0	1.3	-1	4	3	
48	2	439	21		6	740	-1					75	0	0		19.0		0		0	
49	2	930	106	80.0	22	90	35*	42	.215	4.00	30	53	2400*	100	2	20.0	1.6	-1	4	3	
49	2	422*	21		7	964	-1					104	0	0		19.0		0		152	
50	2	930	106	80.0	22	90	43*	42	.215	4.00	30	53	2400*	100	1	20.0	1.9	-1	4	3	
50	2	367*	21		8	1000	-1					110	0	0		18.0		0		152	

02/16/72

TEST NO	TYPE TEST	FUEL TYPE	TANK TYPE	FUEL VOL (GAL)	TRAJ PHASE	TEMP FUEL (DEG F)	TEMP THO (DEG F)	(STRIKER (TYPE	THICK (IN)	-- PLATE) SPACE (IN)	ANGLE) (DEG)	(PROJECTILE) (TYPE	VEL) (FPS)	FILL TYPE	FIRE TYPE	TANK PRES (PSIA)	PRESS RISE (PSI)	TIME MAX P (S*100)	INT REA	CRIT I	* SEE DATA SHEET
TEST NO	SPEC TEST	CRIT II	ULL 3THD		CRIT III	CRIT IV	CRIT V	(VIBRATION) (FREQ (CPM)	AMP) (IN)	(SLOSH) (FREQ (CPM)	AMP) (DEG)	CRIT VI	CRIT VII	CRIT VIII		FUEL DEPTH (IN)		CRIT IX		CRIT X	
51	2	400	106	80.0	22	90	43*	42	.215	4.00	30	53	2400*	100	1	20.0	2.3	-1	4	3	
51	2	324	21		9	959	22					178	0	0		18.0		0		152	
52	2	400	106	80.0	22	90	43*	42	.215	4.00	30	53	2400*	100	1	20.0	2.0	-1	4	3	
52	2	263	21		8	962	31					174	0	0		18.0		0		152	
53	2	400	106	80.0	22	90	43*	42	.215	4.00	30	53	2400*	100	2	20.0	2.3	-1	4	3	
53	2	343	21		8	709	-1					132	0	0		18.0		0		152	
54	2	400	106	80.0	22	90	43*	42	.215	4.00	30	53	2400*	100	1	20.0	2.7	-1	4	3	
54	2	253	21		8	473	-1					166	0	0		18.0		0		152	
55	2	400	130	98.0	22	100*	40*	42	.215	1.00	30	53	2400*	100	3	20.0	1.2	-1	4	3	*
55	2	-1	21		32	0	-1					0	0	0		18.0		0		0	
* IMMEDIATE AND EXTREMELY LARGE FIRE																					
56	2	400	130	98.0	22	95	40	42	.215	1.00	30	53	2400*	100	1	20.0	-1.0	-1	4	3	
56	2	-1	21		76	76	-1					-1	0	0		18.0		0		0	
* LOST INSTRUMENTATION - BURNT WIRING ON PREVIOUS SHOT																					
57	2	400	130	98.0	22	97	40	42	.215	1.00	30	53	2400*	100	3	20.0	.4	-1	4	3	*
57	2	-1	21		36	0	-1					6	0	0		18.0		0		0	
* EXTREMELY LARGE EXTERNAL FIRE																					
58	2	400	130	98.0	22	90	37*	42	.215	1.00	30	53	2400*	100	3	20.0	.4	-1	4	-1	*
58	2	-1	21		40	0	-1					6	0	0		18.0		0		0	
* IMMEDIATE AND EXTRA LARGE EXTERNAL FIRE																					
59	2	400	130	98.0	22	95	37*	42	.215	1.00	30	53	2400*	100	3	20.0	0.0	-1	4	3	*
59	2	-1	21		34	0	-1					0	0	0		18.0		0		0	
* IMMEDIATE AND EXTRA LARGE EXTERNAL FIRE																					
60	2	400	130	98.0	22	90	38	42	.215	1.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
60	2	-1	21		18	20	-1					6	0	0		18.0		0		152	

02/16/72

TEST NO	TYPE TEST	FUEL TYPE	TANK TYPE	FUEL VOL (GAL)	TRAJ PHASE	TEMP FUEL (DEG F)	TEMP TNK (DEG F)	(STRIKER (TYPE	-- THICK (IN)	PLATE SPACE (IN)	) ANGLE) (DEG)	(PROJECTILE) (TYPE	VEL) (FPS)	FILL TYPE	FIRE TYPE	TANK PRES (PSIA)	PRESS RISE (PSI)	TIME MAX P (S*100)	INT REA	CRIT I	* SEE DATA SHEET
TEST NO	SPEC TEST	CRIT II	ULL ATMO		CRIT III	CRIT IV	CRIT V	(VIBRATION (FREQ (CPM)	) AMP) (IN)	(SLOSH (FREQ (CPM)	) AMP) (DEG)	CRIT VI	CRIT VII	CRIT VIII		FUEL DEPTH (IN)		CRIT IX		CRIT X	
61	2	430	170	98.0	22	90	38	42	.215	1.00	30	53	2400*	100	2	20.0	.8	-1	4	3	
61	2	-1	21		16	58	-1					10	0	0		18.0		0		152	
62	2	400	130	98.0	22	95	40	42	.215	1.00	30	53	2400*	100	1	20.0	.4	-1	4	-1	
62	2	-1	21		-1	-1	-1					5	0	0		18.0		0		152	
63	2	400	130	98.0	22	90	45	42	.215	1.00	30	53	2400*	100	1	20.0	0.0	-1	4	1	
63	2	-1	21		1	60	-1					10	0	0		18.0		0		152	
64	2	400	170	98.0	22	95	48*	42	.215	1.00	30	53	2400*	100	2	20.0	.5	-1	1	3	
64	2	-1	21		16	74	-1					35	0	0		18.0		0		0	
65	2	400	170	98.0	22	95	48*	42	.215	1.00	30	53	2400*	100	1	20.0	.4	-1	4	3	
65	2	-1	21		16	40	-1					4	0	0		18.0		0		0	
66	2	400	170	98.0	22	95	32*	42	.215	1.00	30	53	2400*	100	2	20.0	.4	-1	1	3	
66	2	-1	21		30	36	-1					24	0	0		18.0		0		0	
67	2	400	130	98.0	22	90	33*	42	.215	1.00	30	53	2400*	100	2	20.0	-1.0	-1	4	3	*
67	2	-1	21		20	0	-1					-1	0	0		18.0		0		0	

* FIRE SHOT OUT PENETRATION HOLE-REMAINED ON EDGE OF TEST PAD BUT DID NOT FLASH BACK TO THE TANK SPILLAGE

68	2	400	130	98.0	22	90	33*	42	.215	1.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
68	2	-1	21		84	64	-1					6	0	0		18.0		0		0	
69	2	400	130	98.0	22	90	33*	42	.215	1.00	30	53	2400*	100	1	20.0	.4	-1	4	3	
69	2	331+	21		3	206	-1					35	0	0		18.0		0		152	
70	2	400	130	98.0	22	90	33*	42	.215	1.00	30	53	2400*	100	1	20.0	.4	-1	4	1	
70	2	201	21		1	132	-1					25	0	0		18.0		0		152	

02/16/72

TEST NO / TEST NO	TYPE TEST / SPEC TEST	FUEL TYPE / CRIT II	TANK TYPE / ULL ATMO	FUEL VOL (GAL)	TRAJ PHASE / CRIT III	TEMP FUEL (DEG F) / CRIT IV	TEMP TNO (DEG F) / CRIT V	(STRIKER (TYPE / (VIBRATION) (FREQ (CPM)	THICK (IN) / AMP) (IN)	-- PLATE) SPACE (IN) / (SLOSH) (FREQ (CPM)	ANGLE) (DEG) / AMP) (DEG)	(PROJECTILE) (TYPE / CRIT VI	VEL) (FPS) / CRIT VII	FILL TYPE / CRIT VIII	FIRE TYPE	TANK PRES (PSIA) / FUEL DEPTH (IN)	PRESS RISE (PSI)	TIME MAX P (S*100) / CRIT IX	INT RES	CRIT I / CRIT X	* SEE DATA SHEET
71	2	300	130	98.0	22	95	33*	42	.215	1.00	30	53	2400*	100	1	20.0	.7	-1	4	3	
71	2	344*	21		2	252	-1					28	0	0		18.0		0		152	
72	2	300	130	98.0	22	95	33*	42	.215	1.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
72	2	-1	21		2	66	-1					0	0	0		18.0		0		152	
73	2	400	80	60.0	22	98	42*	42	.215	9.00	30	53	2400*	100	1	15.0	0.0	-1	4	3	
73	2	340	21		10	-1	48					56	52	7		18.0		23		152	
74	2	400	80	60.0	22	90	44*	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
74	2	357	21		7	40	38					84	48	10		18.0		23		152	
75	2	400	80	60.0	22	95	49*	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
75	2	342	21		6	248	7					46	0	0		18.0		23		152	
76	2	400	80	60.0	22	95	49*	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	*
76	2	307	21		7	-1	-1					0	0	0		18.0		23		152	
* STANDOFF PRESSURE LINE BLOWN OFF ON PREVIOUS SHOT																					
77	2	400	80	60.0	22	95	40*	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
77	2	238	21		10	-1	36					60	0	0		18.0		23		152	
78	2	400	80	60.0	22	90	49*	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
78	2	342	21		10	-1	54					74	0	0		18.0		23		152	
79	2	400	80	60.0	22	90	49*	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
79	2	257	21		11	268	20					60	0	0		18.0		23		152	
80	2	300	80	60.0	22	90	39*	42	.215	9.00	30	53	2400*	100	1	15.0	0.0	-1	4	3	
80	2	181	21		6	-1	21					40	0	0		18.0		23		152	

02/16/72

TEST NO	TYPE TEST	FUEL TYPE	TANK TYPE	FUEL VOL (GAL)	TRAJ PHASE	TEMP FUEL (DEG F)	TEMP TND (DEG F)	(STRIKER (TYPE	-- THICK (IN)	PLATE SPACE (IN)	) ANGLE) (DEG)	(PROJECTILE) (TYPE	VEL) (FPS)	FILL TYPE	FIRE TYPE	TANK PRES (PSIA)	PRESS RISE (PSI)	TIME MAX P (S*100)	INT REA	CRIT I	* SEE DATA SHEET
TEST NO	SPEC TEST	CRIT II	ULL ATMO		CRIT III	CRIT IV	CRIT V	(VIBRATION) (FREQ (CPM)	AMP) (IN)	(SLOSH) (FREQ (CPM)	AMP) (DEG)	CRIT VI	CRIT VII	CRIT VIII		FUEL DEPTH (IN)		CRIT IX		CRIT X	
81	2	910	80	60.0	22	90	39*	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
81	2	277	21		28	305	76					118	58	25		18.0		23		152	
82	2	930	80	60.0	22	90	42*	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	*
82	2	309	21		11	-1	58					125	92	34		18.0		23		152	
* FIRE REIGNITED IN STANDOFF																					
83	2	800	80	60.0	22	90	42*	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	*
83	2	257	21		14	327	41					59	0	0		18.0		23		152	
* FIRE REIGNITED IN STANDOFF																					
84	2	930	80	60.0	22	90	42*	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
84	2	259	21		8	-1	70					52	0	0		18.0		23		152	
85	2	900	80	60.0	22	95	42*	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	*
85	2	257	21		10	-1	17					59	0	0		18.0		23		152	
* FIRE REIGNITED IN STANDOFF																					
86	2	900	80	60.0	22	90	39	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
86	2	410	21		11	36	29					39	0	0		18.0		101		507	
87	2	930	80	60.0	22	90	38	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	*
87	2	225	21		9	172	29					45	0	0		18.0		101		507	
* FIRE REIGNITED IN STANDOFF																					
88	2	900	50	60.0	22	90	38*	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	*
88	2	254	21		10	234	79					45	0	0		18.0		101		507	
* FIRE REIGNITED IN STANDOFF																					
89	2	990	80	60.0	22	90	78*	42	.215	9.00	30	53	2400*	100	1	20.0	-1.0	-1	4	3	
89	2	145	21		9	174	-1					-1	0	0		18.0		101		507	
90	2	900	80	60.0	22	90	34	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	*
90	2	229	21		24	146	23					84	0	0		18.0		101		507	
* FIRE REIGNITED IN STANDOFF																					

02/16/72

TEST NO	TYPE TEST	FUEL TYPE	TANK TYPE	FUEL VOL (GAL)	TRAJ PHASE	TEMP FUEL (DEG F)	TEMP THO (DEG F)	(STRIKER (TYPE	THICK (IN)	-- PLATE) SPACE (IN)	ANGLE) (DEG)	(PROJECTILE) (TYPE	VEL) (FPS)	FILL TYPE	FIRE TYPE	TANK PRES (PSIA)	PRESS RISE (PSI)	TIME MAX P (S*100)	INT REA	CRIT I	* SEE DATA SHEET
TEST NO	SPEC TEST	CRIT II	ULL ATMO		CRIT III	CRIT IV	CRIT V	(VIBRATION (FREQ (CPM)	AMP) (IN)	(SLOSH (FREQ (CPM)	AMP) (DEG)	CRIT VI	CRIT VII	CRIT VIII		FUEL DEPTH (IN)		CRIT IX		CRIT X	
91	2	400	80	60.0	22	90*	32	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
91	2	311	21		16	26	24					64	0	0		18.0		101		507	
92	2	400	80	60.0	22	90	45*	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
92	2	275	21		6	42	20					74	0	0		18.0		101		507	
93	2	400	80	60.0	22	90	45*	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
93	2	192	21		0	156	23					70	0	0		18.0		101		507	
94	2	400	80	60.0	22	88	45*	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
94	2	142	21		8	222	66					64	0	0		18.0		101		507	
95	2	400	80	60.0	22	90	45*	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
95	2	213	21		8	209	36					48	0	0		18.0		101		507	
96	2	400	80	60.0	22	90	45*	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
96	2	413*	21		6	54	23					66	0	0		18.0		101		507	
97	2	400	80	60.0	22	90	45*	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
97	2	210	21		8	44	25					60	0	0		18.0		101		507	
98	2	400	80	60.0	22	90	40*	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
98	2	257	21		8	136	14					38	0	0		18.0		96		152	
99	2	400	80	60.0	22	90	40*	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
99	2	91	21		16	222	30					56	0	0		18.0		96		152	
100	2	400	80	60.0	22	90	40*	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
100	2	214	21		26	40	30					66	0	0		18.0		96		152	

02/15/72

TEST NO / TEST NO	TYPE TEST / SPEC TEST	FUEL TYPE / CRIT II	TANK TYPE / ULL ATMO	FUEL VOL (GAL)	TRAJ PHASE / CRIT III	TEMP FUEL (DEG F) / CRIT IV	TEMP TNO (DEG F) / CRIT V	STRIKER TYPE / VIBRATION FREQ (CPM)	STRIKER THICK (IN) / VIBRATION AMP (IN)	PLATE SPACE (IN) / SLOSH FREQ (CPM)	PLATE ANGLE (DEG) / SLOSH AMP (DEG)	PROJECTILE TYPE / CRIT VI	PROJECTILE VEL (FPS) / CRIT VII	FILL TYPE / CRIT VIII	FIRE TYPE	TANK PRES (PSIA) / FUEL DEPTH (IN)	PRESS RISE (PSI)	TIME MAX P (S*100) / CRIT IX	INT REA	CRIT I / CRIT X	* SEE DATA SHEET
101	2	400	80	60.0	22	90	40*	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
101	2	196	21		30	110	44					94	78	30		18.0		96		152	
102	2	400	80	60.0	22	90	48*	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
102	2	268	21		25	32	40					54	0	0		18.0		325		507	
103	2	400	80	60.0	22	90	48*	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
103	2	252	21		8	184	40					65	0	0		18.0		325		507	
104	2	400	80	60.0	22	90	48*	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
104	2	234	21		19	422	36					64	0	0		18.0		325		507	
105	2	400	80	60.0	22	90	48*	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
105	2	208	21		14	64	42					76	0	0		18.0		325		507	
106	2	800	80	60.0	22	90	49	42	.215	9.00	30	53	2400*	100	1	20.0	-1.0	-1	4	3	
106	2	42	21		37	82	-1					-1	0	0		18.0		325		507	
107	2	800	80	60.0	22	90	50	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
107	2	91	21		16	78	27					162	0	0		18.0		325		507	
108	2	800	80	60.0	22	90	50	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
108	2	48	21		43	128	26					226	0	0		18.0		325		507	
109	2	800	80	60.0	22	90	50	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
109	2	78	21		12	122	26					216	0	0		18.0		325		507	
110	2	800	80	60.0	22	90	54	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
110	2	771	21		7	36	17					48	0	0		18.0		96		152	

02/16/72

TEST NO	TYPE TEST	FUEL TYPE	TANK TYPE	FUEL VOL (GAL)	TRAJ PHASE	TEMP FUEL (DEG F)	TEMP AMB (DEG F)	(STRIKER (TYPE	THICK (IN)	-- PLATE SPACE (IN)	ANGLE) (DEG)	(PROJECTILE) (TYPE	VEL) (FPS)	FILL TYPE	FIRE TYPE	TANK PRES (PSIA)	PRESS RISE (PSI)	TIME MAX P (S*100)	INT REA	CRIT I	* SEE DATA SHEET
TEST NO	SPEC TEST	CRIT II	ULL ATMO		CRIT III	CRIT IV	CRIT V	(VIBRATION (FREQ (CPM)	) AMP) (IN)	(SLOSH (FREQ (CPM)	) AMP) (DEG)	CRIT VI	CRIT VII	CRIT VIII		FUEL DEPTH (IN)		CRIT IX		CRIT X	
111	2	400	80	60.0	22	90	54*	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	*
111	2	-1	21		7	36	10					52	0	0		18.0		96		152	
* FIRE REIGNITED IN STANDOFF																					
112	2	400	80	60.0	22	90	54	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	*
112	2	2604	21		6	26	30					94	0	0		18.0		96		152	
* FIRE REIGNITED IN STANDOFF																					
113	2	400	80	60.0	22	90	55	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
113	2	178	21		8	36	10					74	0	0		18.0		96		152	
114	2	400	80	60.0	22	90	48	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
114	2	269	21		25	60	16					64	0	0		18.0		96		152	
115	2	400	80	60.0	22	90	48	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
115	2	203	21		13	113	8					49	0	0		18.0		96		152	
116	2	400	80	60.0	22	95	48	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
116	2	96	21		16	14	26					242	0	0		18.0		325		507	
117	2	400	80	60.0	22	90	47	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
117	2	55	21		35	10	26					270	0	0		18.0		325		507	
118	2	400	106	80.0	22	90	75	42	.215	4.00	30	53	2400*	100	1	20.0	-1.0	-1	4	3	
118	2	341	21		8	58	16					49	44	10		18.0		18		152	
119	2	400	106	80.0	22	90	75	42	.215	4.00	30	53	2400*	100	1	20.0	4.4	-1	4	3	
119	2	221	21		15	49	56					26	0	0		18.0		18		152	
120	2	400	106	80.0	22	95	75	42	.215	4.00	30	53	2400*	100	1	20.0	.7	-1	4	3	
120	2	10	21		6	68	68					24	0	0		18.0		18		152	

02/15/72

TEST NO	TYPE TEST	FUEL TYPE	TANK TYPE	FUEL VOL (GAL)	TRAJ PHASE	TEMP FUEL (DEG F)	TEMP TWO (DEG F)	(STRIKER (TYPE	THICK (IN)	-- PLATE) SPACE (IN)	ANGLE) (DEG)	(PROJECTILE) (TYPE	VEL) (FPS)	FILL TYPE	FIRE TYPE	TANK PRES (PSIA)	PRESS RISE (PSI)	TIME MAX P (S*100)	INT REA	CRIT I	* SEE DATA SHEET
TEST NO	SPEC TEST	CRIT II	ULL ATMO		CRIT III	CRIT IV	CRIT V	(VIBRATION) (FREQ (CPM)	AMP) (IN)	(SLOSH) (FREQ (CPM)	AMP) (DEG)	CRIT VI	CRIT VII	CRIT VIII		FUEL DEPTH (IN)		CRIT IX		CRIT X	
121	2	400	106	40.0	22	90	75	42	.215	4.00	30	53	2400*	100	1	20.0	.8	-1	4	3	
121	2	133	21		6	44	41					44	0	0		18.0		18		152	
122	2	400	106	40.0	22	87	56	42	.215	4.00	30	53	2400*	100	1	20.0	.7	-1	4	3	
122	2	313*	21		17	66	8					26	0	0		18.0		18		152	
123	2	400	106	40.0	22	90	59	42	.215	4.00	30	53	2400*	100	1	20.0	.5	-1	4	3	
123	2	-1	21		-1	40	91					68	0	0		18.0		18		152	
124	2	400	106	40.0	22	92	59	42	.215	4.00	30	53	2400*	100	1	20.0	.7	-1	4	3	
124	2	327 +	21		6	33	90					44	0	0		18.0		58		507	
125	2	400	106	40.0	22	90	60	42	.215	4.00	30	53	2400*	100	1	20.0	.4	-1	4	3	
125	2	295	21		8	64	85					48	0	0		18.0		58		507	
126	2	400	106	40.0	22	87	60	42	.215	4.00	30	53	2400*	100	1	20.0	.4	-1	4	3	
126	2	321	21		8	26	91					34	0	0		18.0		58		507	
127	2	400	106	40.0	22	93	60	42	.215	4.00	30	53	2400*	100	1	20.0	.4	-1	4	3	*
127	2	391*	21		6	26	86					54	0	0		18.0		58		507	
128	2	400	106	40.0	22	92	57	42	.215	4.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
128	2	-1	21		-1	26	106					32	0	0		18.0		18		152	
129	2	400	106	40.0	22	93	61	42	.215	4.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
129	2	-1	21		5	158	100					56	0	0		18.0		18		152	
130	2	400	106	40.0	22	92	60*	42	.215	4.00	30	53	2400*	100	1	20.0	-1.0	-1	4	3	
130	2	260	21		7	88	-1					-1	0	0		18.0		18		152	

* PREMATURE SHUT DOWN OF ENGINE RESULTED IN STANDOFF FIRE SPREADING AND IGNITING FUEL ON THE GROUND

02/16/72

TEST NO	TYPE TEST	FUEL TYPE	TANK TYPE	FUEL VOL (GAL)	TRAJ PHASE	TEMP FUEL (DEG F)	TEMP TNO (DEG F)	(STRIKER (TYPE	THICK (IN)	-- PLATE) SPACE (IN)	ANGLE) (DEG)	(PROJECTILE) (TYPE	VEL) (FPS)	FILL TYPE	FIRE TYPE	TANK PRES (PSIA)	PRESS RISE (PSI)	TIME MAX P (S*100)	INT REA	CRIT I	* SEE DATA SHEET
TEST NO	SPEC TEST	CRIT II	ULL ATMO		CRIT III	CRIT IV	CRIT V	(VIBRATION) (FREQ) (CPM)	AMP) (IN)	(SLOSH) (FREQ) (CPM)	AMP) (DEG)	CRIT VI	CRIT VII	CRIT VIII		FUEL DEPTH (IN)		CRIT IX		CRIT X	
131	2	900	106	80.0	22	90	60*	42	.215	4.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
131	2	104	21		0	6	86					70	0	0		18.0		18		152	
132	2	900	106	80.0	22	95	60*	42	.215	4.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
132	2	279	21		6	26	101					54	0	0		18.0		18		152	
133	2	900	106	80.0	22	90	60*	42	.215	4.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	*
133	2	409	21		7	34	114					49	0	0		18.0		18		152	
* FLAMES SHOT OUT EXHAUST PIPE DUE TO STANDOFF FIRE																					
134	2	900	106	80.0	22	87	67	42	.215	4.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
134	2	277	21		7	22	117					56	0	0		11.0		58		507	
135	2	900	106	80.0	22	93	67	42	.215	4.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	*
135	2	375 +	21		4	-1	77					46	0	0		18.0		58		507	
* LEAK IN TANK																					
136	2	930	106	80.0	22	95	67	42	.215	4.00	30	53	2400*	100	1	20.0	.4	-1	4	3	
136	2	-1	21		7	22	76					69	0	0		18.0		58		507	
137	2	900	106	80.0	22	90	63	42	.215	4.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	*
137	2	339 +	21		2	-1	63					74	0	0		18.0		58		507	
* FIRE IN STANDOFF CONTINUED AFTER ENGINE SHUTDOWN, EXTINGUISHED ITSELF																					
138	2	900	106	80.0	22	90	49	42	.215	4.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	*
138	2	275	21		6	200	26					24	0	0		18.0		75		152	
* BAD LEAK IN TANK																					
139	2	900	105	80.0	22	90	49	42	.215	4.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
139	2	411*	21		0	50	30					111	36	30		18.0		75		152	
140	2	900	106	80.0	22	90	50	42	.215	4.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
140	2	415 +	21		11	256	56					74	0	0		18.0		75		152	

02/16/72

TEST NO	TYPE TEST	FUEL TYPE	TANK TYPE	FUEL VOL (GAL)	TRAJ PHASE	TEMP FUEL (DEG F)	TEMP TWO (DEG F)	(STRIKER (TYPE	THICK (IN)	-- PLATE) SPACE (IN)	ANGLE (DEG)	(PROJECTILE) (TYPE	VEL) (FPS)	FILL TYPE	FIRE TYPE	TANK PRES (PSIA)	PRESS RISE (PSI)	TIME MAX P (S*100)	INT REA	CRIT I	* SEE DATA SHEET
TEST NO	SPEC TEST	CRIT II	ULL ATMO		CRIT III	CRIT IV	CRIT V	(VIBRATION) (FREQ (CPM)	AMP) (IN)	(SLOSH) (FREQ (CPM)	AMP) (DEG)	CRIT VI	CRIT VII	CRIT VIII		FUEL DEPTH (IN)		CRIT IX		CRIT X	
141	2	400	106	80.0	22	90	50	42	.215	4.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
141	2	4212+	21		18	258	62					74	0	0		18.0		75		152	
142	2	400	106	80.0	22	90	85	42	.215	4.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	*
142	2	431+	21		9	54	49					34	0	0		18.0		180		507	
	* STANDOFF FIRE SHOT FLAMES OUT VENT																				
143	2	400	106	80.0	22	92	85	42	.215	4.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
143	2	4570+	21		18	26	96					36	0	0		18.0		180		507	
144	2	400	106	80.0	22	95	87	42	.215	4.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	
144	2	1474	21		16	24	131					28	0	0		18.0		180		507	
145	2	400	106	80.0	22	90	72	42	.215	4.00	30	53	2400*	100	1	20.0	.5	-1	4	-0	*
145	2	3844	21		16	44	15					116	18	56		18.0		180		507	
	* FIRE IN STANDOFF - HIGH PRESSURE BROKE VENTILATION EXHAUST TUBE																				
146	2	410	106	80.0	22	95	68	42	.215	4.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	*
146	2	132	21		16	26	58					34	0	0		18.0		180		507	
	* TANK PRESSURE BROKE WELD																				
147	2	400	106	80.0	22	90	52	42	.215	4.00	30	53	2400*	100	1	20.0	.3	-1	4	3	
147	2	717+	21		11	42	20					123	18	51		18.0		180		507	
148	2	400	106	80.0	22	90	52	42	.215	4.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	*
148	2	326+	21		10	36	33					120	32	62		18.0		180		507	
	* FIRE IN STANDOFF WITH FLAMES OUT EXHAUST TUBE AND FLASH OUT STRIKER PLATE																				
149	2	400	106	80.0	22	90	54	42	.215	4.00	30	53	2400*	100	1	20.0	.3	2	4	3	*
149	2	157	21		6	12	113					32	0	0		18.0		180		507	
	* STANDOFF FIRE APPEARED OUT BUT REIGNITED AT REAR OF ARTICLE AFTER ENGINE SHUT DOWN - TEST ARTICLE DAMAGE																				
150	2	400	106	80.0	22	90	54	42	.215	4.00	30	53	2400*	100	3	20.0	.4	-1	4	3	*
150	2	-1	21		12	26	34					144	34	86		18.0		75		152	
	* EXHAUST TUBE BLOWN OFF AND STANDOFF FIRE CAUSED EXTERNAL FIRE BEHIND TEST ARTICLE																				

02/16/72

TEST NO	TYPE TEST	FUEL TYPE	TANK TYPE	FUEL VOL (GAL)	TRAJ PHASE	TEMP FUEL (DEG F)	TEMP THO (DEG F)	(STRIKER (TYPE	THICK (IN)	-- PLATE) SPACE (IN)	ANGLE) (DEG)	(PROJECTILE) (TYPE	VEL) (FPS)	FILL TYPE	FIRE TYPE	TANK PRES (PSIA)	PRESS RISE (PSI)	TIME MAX P (S*100)	INT REA	CRIT I	* SEE DATA SHEET
TEST NO	SPEC TEST	CRIT II	ULL ATMO		CRIT III	CRIT IV	CRIT V	(VIBRATION) (FREQ (CPM)	AMP) (IN)	(SLOSH) (FREQ (CPM)	AMP) (DEG)	CRIT VI	CRIT VII	CRIT VIII		FUEL DEPTH (IN)		CRIT IX		CRIT X	
151	2	400	106	80.0	22	90	69	42	.215	4.00	30	53	2400*	100	1	20.0	.5	-1	4	3	
151	2	749	21		12	92	113					29	0	0		18.0		75		152	
152	2	400	106	80.0	22	90	69	42	.215	4.00	30	53	2400*	100	1	20.0	.4	-1	4	3	
152	2	233	21		0	100	99					54	0	0		18.0		75		152	
153	2	400	106	80.0	22	90	59	42	.215	4.00	30	53	2400*	100	1	20.0	.5	-1	4	3	*
153	2	298	21		0	194	76					52	0	0		18.0		75		152	
* FIRE IN STANDOFF - VENT EXHAUST TUBE BLOWN OFF																					
154	2	400	106	80.0	22	90	70	42	.215	4.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	*
154	2	-1	21		0	78	93					40	0	0		18.0		75		152	
* FIRE IN REAR OF TEST ARTICLE																					
155	2	400	80	60.0	22	75	80*	42	.215	9.00	30	53	2400*	100	2	17.0	1.3	-1	4	3	
155	2	-1	21		6	566	20					170	88	30		18.0		23		152	
* LEAK IN MAIN TANK DUE TO PREVIOUS TEST																					
156	2	400	80	60.0	2	80	80*	42	.215	9.00	30	53	2400*	100	1	17.0	.8	13	4	3	
156	2	-1	21		7	202	46					146	0	0		18.0		23		152	
157	2	400	80	60.0	22	80	80*	42	.215	9.00	30	53	2400*	100	1	20.0	2.1	14	4	3	
157	2	201	21		11	274	64					132	0	0		18.0		23		152	
158	2	400	80	60.0	22	75	70*	42	.215	9.00	30	53	2400*	100	1	20.0	.4	-1	4	3	
158	2	312	21		8	-1	31					72	0	0		18.0		23		152	
159	2	400	80	60.0	22	90	78*	42	.215	9.00	30	53	2400*	100	1	15.0	.3	-1	4	3	
159	2	225	21		8	294	37					70	0	0		18.0		23		152	
160	2	400	80	60.0	22	90	80*	42	.215	9.00	30	53	2400*	100	1	15.0	.5	-1	4	3	
160	2	472*	21		11	239	14					46	0	0		18.0		23		152	

02/15/72

TEST NO	TYPE TEST	FUEL TYPE	TANK TYPE	FUEL VOL (GAL)	TRAJ PHASE	TEMP FUEL (DEG F)	TEMP TNO (DEG F)	(STRIKER (TYPE	THICK (IN)	-- PLATE SPACE (IN)	ANGLES) (DEG)	(PROJECTILE) (TYPE	VEL) (FPS)	FILL TYPE	FIRE TYPE	TANK PRES (PSIA)	PRESS RISE (PSI)	TIME MAX P (S*100)	INT REA	CRIT I	* SEE DATA SHEET
TEST NO	SPEC TEST	CRIT II	ULL ATMO		CRIT III	CRIT IV	CRIT V	(VIBRATION (FREQ) (CPM)	) AMP) (IN)	(SLOSH (FREQ) (CPM)	) AMP) (DEG)	CRIT VI	CRIT VII	CRIT VIII		FUEL DEPTH (IN)		CRIT IX		CRIT X	
161	2	430	90	60.0	22	90	80*	42	.215	0.00	30	53	2400	100	1	15.0	.7	-1	4	3	
161	2	450+	21		10	742	31					64	0	0		18.0		23		152	
162	2	400	80	60.0	22	90	90*	42	.215	0.00	30	53	2400*	100	1	15.0	.9	-1	4	3	
162	2	441+	21		9	236	20					52	0	0		18.0		23		152	
163	2	800	90	60.0	22	76	70	42	.215	0.00	30	53	2400*	100	1	20.0	0.0	-1	1	3	
163	2	-1	21		10	456	30					29	0	0		19.0		23		152	
164	2	800	90	60.0	22	78	70	42	.215	0.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	*
164	2	319	21		7	1196	49					43	0	0		19.0		23		152	
* FIRE IN STANDOFF - SECOND PRESSURE AND TEMPERATURE RISE OCCURRED AT 1.5 SECONDS																					
165	2	800	90	60.0	22	75	72	42	.215	0.00	30	53	2400*	100	1	20.0	0.0	-1	4	3	*
165	2	436	21		6	536	41					64	0	0		18.0		23		152	
* FIRE IN STANDOFF - SECOND PRESSURE AND TEMPERATURE RISE OCCURRED AT 2.7 SECONDS																					
166	2	800	90	60.0	22	90	72	42	.215	9.00	30	53	2400*	100	1	15.0	1.7	13	4	3	*
166	2	457+	21		10	-7	42					64	0	0		18.0		23		152	
* LARGE CLOUD OF SMOKE AND FLAMES SHOT OUT VENT TUBE																					
167	2	330	90	60.0	22	90	72	42	.215	0.00	30	53	2400*	100	1	15.0	1.6	10	4	3	
167	2	438+	21		8	604	57					76	0	0		18.0		23		152	
168	2	800	90	60.0	22	90	72	42	.215	0.00	30	53	2400*	100	1	15.0	2.1	6	2	3	
168	2	0	21		8	-7	41					49	0	0		19.0		23		152	
169	2	400	90	60.0	22	75	77	42	.215	9.00	70	53	2400*	100	1	20.0	1.3	8	4	3	*
169	2	255 +	21		12	366	48					70	0	0		18.0		97		152	
* FIRE IN STANDOFF AND OUT EXHAUST TUBE																					
170	2	400	90	60.0	22	75	77	42	.215	0.00	30	53	2400*	100	2	20.0	2.4	9	4	3	*
170	2	298 +	21		11	246	54					60	0	0		19.0		97		152	
* FIRE OUT EXHAUST TUBE																					

02/16/72

TEST NO	TYPE TEST	FUEL TYPE	TANK TYPE	FUEL VOL (GAL)	TRAJ PHASE	TEMP FUEL (DEG F)	TEMP THO (DEG F)	(STRIKER (TYPE	THICK (IN)	-- PLATE SPACE (IN)	) ANGLE (DEG)	(PROJECTILE) (TYPE	VEL) (FPS)	FILL TYPE	FIRE TYPE	TANK PRES (PSIA)	PRESS RISE (PSI)	TIME MAX P (S*100)	INT REA	CRIT I	* SEE DATA SHEET
TEST NO	SPEC TEST	CRIT II	ULL ATMO		CRIT III	CRIT IV	CRIT V	(VIBRATION (FREQ (CPM)	) AMP) (IN)	(SLOSH (FREQ (CPM)	) AMP) (DEG)	CRIT VI	CRIT VII	CRIT VIII		FUEL DEPTH (IN)		CRIT IX		CRIT X	
171	2	400	90	60.0	22	75	77	42	.215	0.00	30	53	2400*	100	1	20.0	.8	8	4	3	*
171	2	193 +	21		12	796	55					88	0	0		18.0		97		152	
	* FLAMES SHOT OUT ENTRANCE NOZZLE - TANK LEAKING BADLY																				
172	2	400	90	60.0	22	92	78	42	.215	0.00	30	53	2400*	100	1	15.0	1.2	-1	4	3	
172	2	530 +	21		7	654	49					72	0	0		18.0		97		152	
173	2	410	90	60.0	22	90	75	42	.215	0.00	30	53	2400*	100	1	15.0	.9	-1	4	3	*
173	2	505	21		6	-7	49					63	0	0		18.0		97		152	
	* FLAMES SHOT OUT VENT TUBE																				
174	2	400	90	60.0	22	90	78	42	.215	0.00	30	53	2400*	100	1	15.0	.8	-1	4	3	
174	2	-1	21		9	450	41					66	0	0		18.0		97		152	
175	2	400	90	60.0	22	75	90	42	.215	0.00	30	53	2400*	100	1	20.0	.5	-1	4	3	*
175	2	463 +	21		12	1160	44					86	0	0		18.0		97		152	
	* OSCILLOGRAPH RECORD INDICATES A TEMPERATURE RISE IN ULLAGE BUT NO PRESSURE RISE IN TANK - SECOND PRESSURE RISE IN STANDOFF																				
176	2	410	90	60.0	22	75	90	42	.215	0.00	30	53	2400*	100	1	20.0	.5	-1	4	3	*
176	2	296	21		7	1166	47					122	0	0		18.0		97		152	
	* SECOND PRESSURE RISE IN STANDOFF OCCURRED																				
177	2	400	90	60.0	22	75	90*	42	.215	0.00	30	53	2400*	100	1	20.0	-1.0	-1	1	-1	
177	2	-1	21		-1	152	50					90	0	0		18.0		97		152	
178	2	400	90	60.0	22	87	87	42	.215	0.00	30	53	2400*	100	1	15.0	1.5	-1	4	3	
178	2	343	21		10	-3	45					88	0	0		14.0		97		152	
179	2	400	90	60.0	22	30	87*	42	.215	0.00	30	53	2400*	100	1	15.0	1.6	-1	4	3	
179	2	670 +	21		6	1122	14					137	58	45		15.0		97		152	
180	2	400	90	60.0	22	30	97*	42	.215	0.00	30	53	2400*	100	1	15.0	1.5	14	4	3	
180	2	452 +	21		7	1172	16					145	50	55		18.0		97		152	

02/15/72

TEST NO	TYPE TEST	FUEL TYPE	TANK TYPE	FUEL VOL (GAL)	TRAJ PHASE	TEMP FUEL (DEG F)	TEMP TMO (DEG F)	(STRIKER (TYPE	THICK (IN)	-- PLATE SPACE (IN)	ANGLE) (DEG)	(PROJECTILE) (TYPE	VEL) (FPS)	FILL TYPE	FIRE TYPE	TANK PRES (PSIA)	PRESS RISE (PSI)	TIME MAX P (S*100)	INT REA	CRIT I	* SEE DATA SHEET
TEST NO	SPEC TEST	CRIT II	ULL ATMO		CRIT III	CRIT IV	CRIT V	(VIBRATION (FREQ (CPM)	AMP) (IN)	(SLOSH (FREQ (CPM)	AMP) (DEG)	CRIT VI	CRIT VII	CRIT VIII		FUEL DEPTH (IN)		CRIT IX		CRIT X	
181	2	400	106	90.0	22	90	86	73	.215	4.00	30	53	2400*	100	1	20.0	0.0	-1	1	-1	*
181	2	-1	21		-1	-1	-1					0	0	0		18.0		18		152	
* 10 PPI FOAM IN STANDOFF - NO REACTION BETWEEN INCENDIARY AND FUEL																					
182	2	400	106	90.0	22	90	87	73	.215	4.00	30	53	2400*	100	1	20.0	0.0	-1	1	-1	*
182	2	-1	21		-1	90	-1					0	0	0		18.0		18		152	
* 10 PPI FOAM IN STANDOFF																					
183	2	400	106	90.0	22	90	87	73	.215	4.00	30	53	2400*	100	1	20.0	0.0	-1	1	-1	*
183	2	-1	21		-1	146	-1					6	0	0		18.0		18		152	
* 10 PPI FOAM IN STANDOFF																					
184	2	400	106	90.0	22	90	85	73	.215	4.00	30	53	2400*	100	1	20.0	0.0	-1	1	-1	*
184	2	-1	21		-1	302	-1					6	0	0		18.0		18		152	
* 10 PPI FOAM IN STANDOFF																					
185	2	400	106	90.0	22	90	85	73	.215	4.00	30	53	2400*	100	1	20.0	0.0	-1	1	-1	*
185	2	-1	21		-1	146	-1					4	0	0		18.0		18		152	
* 10 PPI FOAM IN STANDOFF																					
186	2	400	106	90.1	22	90	85	73	.215	4.00	30	53	2400*	100	1	20.0	0.0	-1	1	-1	*
186	2	-1	21		-1	68	-1					0	0	0		18.0		18		152	
* 10 PPI FOAM IN STANDOFF																					
187	2	400	106	8.0	11	90	58	42	.215	4.00	30	53	2400*	200	1	15.0	0.0	-1	4	3	*
187	2	50	21		7	-3	41					12	0	0		2.0		18		152	
* VAPOR SHOT - FOAM IN TANK - FOAM DAMAGED																					
188	2	400	106	8.9	11	90	89	42	.215	4.00	30	53	2400*	200	1	15.0	0.0	-1	4	3	*
188	2	17	21		0	-3	35					10	0	0		2.0		18		152	
* VAPOR SHOT - FOAM IN TANK- FOAM BURNT																					
189	2	400	106	8.0	11	90	82	42	.215	4.00	30	53	2400*	200	1	15.0	0.0	-1	4	3	*
189	2	447*	21		6	-7	34					10	0	0		2.0		18		152	
* VAPOR SHOT - FOAM IN TANK - FOAM BURNT BADLY																					
190	2	400	106	8.7	11	90	84	42	.215	4.00	30	53	2400*	200	1	15.0	0.0	-1	4	3	*
190	2	469*	21		0	-3	35					15	0	0		2.0		18		152	
* VAPOR SHOT - FOAM IN TANK - LITTLE DAMAGE TO FOAM																					

02/16/72

TEST NO / TEST NO	TYPE TEST / SPEC TEST	FUEL TYPE / CRIT II	TANK TYPE / ULL ATMO	FUEL VOL (GAL)	ULL PHASE / CRIT III	TEMP FUEL (DEG F) / CRIT IV	TEMP TWO (DEG F) / CRIT V	(STRIKER TYPE / (VIBRATION FREQ (CPM)	-- THICK (IN) / AMP) (IN)	PLATE SPACE (IN) / (SLOSH FREQ (CPM)	) ANGLE (DEG) / AMP) (DEG)	(PROJECTILE) (TYPE / CRIT VI	VEL) (FPS) / CRIT VII	FILL TYPE / CRIT VIII	FIRE TYPE	TANK PRES (PSIA) / FUEL DEPTH (IN)	PRESS RISE (PSI)	TIME MAX P (S*100) / CRIT IX	INT REA	CRIT I / CRIT X	* SEE DATA SHEET
191	2	400	106	4.2	11	33	56	42	.215	4.00	30	53	2400*	200	1	15.0	0.0	-1	4	3	*
191	2	469*	21		8	-3	77					18	0	0		2.0		18		152	
* VAPOR SHOT - FOAM IN TANK - LITTLE DAMAGE TO FOAM																					
192	2	400	106	4.0	11	30	58	42	.215	4.00	30	53	2400*	200	1	15.0	0.0	-1	4	3	*
192	2	442*	21		7	-3	74					12	0	0		2.0		18		152	
* VAPOR SHOT - FOAM IN TANK																					
193	2	400	135	30.0	22	30	82	42	.215	0.00	30	53	2400*	100	1	20.0	3.0	4	2	9	
193	2	0	21		-1	0	-1					-1	0	0		18.0		0		152	
* PLEXIGLASS WINDOW BROKEN DURING TEST																					
194	2	400	135	90.0	22	30	72	42	.215	0.00	30	53	2400*	100	3	20.0	3.2	4	2	9	
194	2	0	21		-1	0	-1					-1	0	0		18.0		0		152	
195	2	400	135	90.0	22	90	76	42	.215	0.00	30	53	2400*	100	3	20.0	2.2	3	2	9	*
195	2	0	21		-1	0	-1					-1	0	0		18.0		0		152	
* EXTERNAL FIRE STARTED AT REAR OF TEST ARTICLE BUT NEVER GOT BACK TO STRIKER PLATE																					
196	2	400	135	90.0	22	30	70	42	.215	0.00	30	53	2400*	100	2	20.0	2.6	4	2	9	
196	2	0	21		-1	0	-1					-1	0	0		18.0		0		152	
197	2	400	135	90.0	22	90	74	42	.215	0.00	30	53	2400*	100	2	20.0	3.0	3	2	9	
197	2	0	21		-1	0	-1					-1	0	0		18.0		0		152	
198	2	400	135	90.0	22	90	76	42	.215	0.00	30	53	2400*	100	2	20.0	2.2	5	2	9	
198	2	0	21		-1	0	-1					-1	0	0		18.0		0		152	
201	2	400	81	60.0	22	90	47	42	.125	0.00	30	53	2400*	100	1	15.0	2.7	10	2	6	
201	2	0	21		0	0	-1					0	0	0		18.0		0		152	
202	2	400	81	60.0	22	90*	47	42	.125	0.00	30	53	2400*	100	1	15.0	2.9	9	2	6	
202	2	0	21		0	0	-1					0	0	0		18.0		0		152	

02/16/72

TEST NO	TYPE TEST	FUEL TYPE	TANK TYPE	FUEL VOL (GAL)	TRAJ PHASE	TEMP FUEL (DEG F)	TEMP TMP (DEG F)	(STRIKER (TYPE	-- THICK (IN)	PLATE SPACE (IN)	) ANGLE (DEG)	(PROJECTILE) (TYPE	VEL) (FPS)	FILL TYPE	FIRE TYPE	TANK PRES (PSIA)	PRESS RISE (PSI)	TIME MAX P (S*100)	INT REA	CRIT I	* SEE DATA SHEET
TEST NO	SPEC TEST	CRIT II	ULL ATMO		CRIT III	CRIT IV	CRIT V	(VIBRATION FREQ (CPM)	) AMP (IN)	(SLOSH FREQ (CPM)	) AMP (DEG)	CRIT VI	CRIT VII	CRIT VIII		FUEL DEPTH (IN)		CRIT IX		CRIT X	
203	2	400	81	60.0	22	90	42	42	.125	0.00	30	53	2400*	100	2	15.0	2.3	11	2	6	
203	2	0	21		0	0	-1					0	0	0		18.0		0		152	
204	2	400	81	60.0	22	90	42	42	.125	0.00	30	53	2400*	100	2	15.0	2.6	8	2	6	
204	2	0	21		0	0	-1					0	0	0		18.0		0		152	
205	2	400	81	60.0	22	90	42	42	.125	0.00	30	53	2400*	100	1	15.0	2.6	5	2	6	
205	2	0	21		0	0	-1					0	0	0		18.0		0		152	
206	2	400	81	60.0	22	90	42	42	.125	0.00	30	53	2400*	100	1	15.0	2.7	7	2	6	*
206	2	0	21		0	0	-1					0	0	0		18.0		0		152	

* COMPLETE FAILURE OF STRIKER PLATE, FUEL ALL OVER TEST BED BUT NO INTERNAL OR EXTERNAL FIRE

TEST NO	TYPE TEST	FUEL TYPE	TANK TYPE	FUEL VOL (GAL)	TRAJ PHASE	TEMP FUEL (DEG F)	TEMP TMP (DEG F)	STRIKER TYPE	THICK (IN)	PLATE SPACE (IN)	ANGLE (DEG)	PROJECTILE TYPE	VEL (FPS)	FILL TYPE	FIRE TYPE	TANK PRES (PSIA)	PRESS RISE (PSI)	TIME MAX P (S*100)	INT REA	CRIT I	* SEE DATA SHEET
207	2	400	81	60.0	22	90	46	42	.125	0.00	30	53	2400*	100	1	15.0	3.5	10	2	6	*
207	2	0	21		0	0	-1					0	0	0		18.0		23		152	

* PROJECTILE DID NOT EXIT - STOPPED AFTER SECOND PLATE - TANK DAMAGED DUE TO PROJECTILE

TEST NO	TYPE TEST	FUEL TYPE	TANK TYPE	FUEL VOL (GAL)	TRAJ PHASE	TEMP FUEL (DEG F)	TEMP TMP (DEG F)	STRIKER TYPE	THICK (IN)	PLATE SPACE (IN)	ANGLE (DEG)	PROJECTILE TYPE	VEL (FPS)	FILL TYPE	FIRE TYPE	TANK PRES (PSIA)	PRESS RISE (PSI)	TIME MAX P (S*100)	INT REA	CRIT I	* SEE DATA SHEET
208	2	400	51	60.0	22	90	78	42	.125	0.00	30	53	2400*	100	1	15.0	2.3	10	2	6	
208	2	0	21		0	0	-1					0	0	0		18.0		23		152	
209	2	400	81	60.0	22	90	38	42	.125	0.00	30	53	2400*	100	1	15.0	2.2	22	2	6	
209	2	0	21		0	0	-1					10	0	0		18.0		23		152	
210	2	400	81	60.0	22	90	41	42	.125	0.00	30	53	2400*	100	2	15.0	1.3	17	2	6	
210	2	0	21		0	0	-1					0	0	0		18.0		23		152	
211	2	400	81	60.0	22	90	42	42	.125	0.00	30	53	2400*	100	1	15.0	2.6	10	2	8	
211	2	0	21		0	0	-1					0	0	0		18.0		23		152	
212	2	400	81	60.0	22	90*	40	42	.215	0.00	30	53	2400*	100	1	15.0	1.2	11	2	6	
212	2	0	21		0	0	-1					0	0	0		18.0		23		152	

02/16/72

TEST NO	TYPE TEST	FUEL TYPE	TANK TYPE	FUEL VOL (GAL)	TRAJ PHASE	TEMP FUEL (DEG F)	TEMP TWO (DEG F)	(STRIKER (TYPE	THICK (IN)	-- PLATE) SPACE (IN)	ANGLE (DEG)	(PROJECTILE) (TYPE	VEL) (FPS)	FILL TYPE	FIRE TYPE	TANK PRES (PSIA)	PRESS RISE (PSI)	TIME MAX P (S*100)	INT REA	CRIT I	* SEE DATA SHEET
TEST NO	SPEC TEST	CRIT II	ULL ATMO		CRIT III	CRIT IV	CRIT V	(VIBRATION) (FREQ (CPM)	AMP) (IN)	(SLOSH) (FREQ (CPM)	AMP) (DEG)	CRIT VI	CRIT VII	CRIT VIII		FUEL DEPTH (IN)		CRIT IX		CRIT X	
213	2	400	31	23.0	22	90*	74	42	.215	27.00	30	53	2400*	100	1	15.0	6.6	3	2	3	
213	2	0	21		1	0	-1					0	0	0		18.0		0		152	
214	2	400	31	23.0	22	90	40	42	.215	27.00	30	53	2400*	100	1	15.0	6.4	3	2	5	
214	2	0	21		0	0	-1					0	0	0		18.0		0		152	
215	2	400	31	23.0	22	90	41	42	.215	27.00	30	53	2400*	100	1	15.0	8.0	3	2	5	
215	2	0	21		0	0	-1					0	0	0		18.0		0		152	
216	2	400	31	23.0	22	90	43	42	.215	27.00	30	53	2400*	100	2	15.0	9.0	3	2	3	*
216	2	0	21		1	0	-1					0	0	0		18.0		0		152	
* FLASH FIRE AT ENTRANCE																					
217	2	400	31	23.0	22	87	43	42	.215	27.00	30	53	2400*	100	2	15.0	6.5	3	2	3	
217	2	0	21		2	0	-1					0	0	0		18.0		0		152	
218	2	400	31	23.0	22	90	45	42	.215	27.00	30	53	2400*	100	1	15.0	6.2	4	6	3	
218	2	5	21		2	0	-1					0	0	0		18.0		0		152	
219	2	400	31	23.0	22	85	48	42	.215	27.00	30	53	2400*	100	1	15.0	6.6	3	2	3	
219	2	0	21		3	0	-1					0	0	0		18.0		7		152	
220	2	400	31	23.0	22	75	49	42	.215	27.00	30	53	2400*	100	2	15.0	14.4	15	6	3	*
220	2	293*	21		6	0	74					139	0	0		18.0		7		152	
* FLASH FIRE AT ENTRANCE - FIRE IN REAR DRY BAY																					
221	2	400	31	23.0	22	90	50	42	.215	27.00	30	53	2400*	100	1	15.0	22.8	9	6	3	
221	2	300 +	21		4	0	70					232	0	0		18.0		7		152	
222	2	400	31	23.0	22	90	56	42	.215	27.00	30	53	2400*	100	1	15.0	6.5	4	6	3	*
222	2	399+	21		4	0	95					57	0	0		18.0		7		152	
* FIRE EXITED THROUGH PROJECTILE HOLE LIKE A BLOW TORCH																					

02/15/72

TEST NO	TYPE TEST	FUEL TYPE	TANK TYPE	FUEL VOL (GAL)	TRAJ CHASE	TEMP FUEL (DEG F)	TEMP TNO (DEG F)	(STRIKER (TYPE	THICK (IN)	-- PLATE) SPACE (IN)	ANGLE) (DEG)	(PROJECTILE) (TYPE	VEL) (FPS)	FILL TYPE	FIRE TYPE	TANK PRES (PSIA)	PRESS RISE (PSI)	TIME MAX P (S*100)	INT REA	CRIT I	* SEE DATA SHEET
TEST NO	SPEC TEST	CRIT II	ULL ATMO		CRIT III	CRIT IV	CRIT V	(VIBRATION) (FREQ (CPM)	AMP) (IN)	(SLOSH) (FREQ (CPM)	AMP) (DEG)	CRIT VI	CRIT VII	CRIT VIII		FUEL DEPTH (IN)		CRIT IX		CRIT X	
223	2	400	31	23.0	22	90	58	42	.215	27.00	30	53	2400*	100	1	15.0	7.6	3	2	5	
223	2	0	21		0	0	-1					0	0	0		18.0		7		152	
224	2	400	31	23.0	22	90*	59	42	.215	27.00	30	53	2400*	100	1	15.0	8.6	4	2	3	
224	2	0	21		6	0	-1					4	0	0		18.0		7		152	
225	2	400	31	23.0	22	90	49	42	.215	27.00	30	53	2400*	100	1	15.0	7.4	3	2	3	
225	2	0	21		4	0	-1					0	0	0		18.0		33		152	
226	2	400	31	23.0	22	90	50	42	.215	27.00	30	53	2400*	100	2	15.0	9.2	4	2	6	
226	2	0	21		0	0	-1					3	0	0		18.0		33		152	
227	2	400	31	23.0	22	87	50	42	.215	27.00	30	53	2400*	100	1	15.0	7.8	4	2	1	
227	2	0	21		-1	0	-1					0	0	0		18.0		33		152	
228	2	400	31	23.0	22	88	48	42	.215	27.00	30	53	2400*	100	1	15.0	8.8	4	2	8	*
228	2	0	21		0	0	-1					0	0	0		18.0		33		152	
* TANK EXIT PLATE DAMAGED																					
229	2	400	31	23.0	22	92	48	42	.215	27.00	30	53	2400*	100	1	15.0	10.8	4	2	6	
229	2	0	21		0	0	-1					4	0	0		18.0		33		152	
230	2	400	31	23.0	22	90*	49	42	.21	27.00	30	53	2400*	100	1	15.0	7.6	4	6	3	
230	2	366 +	21		-1	0	316					30	0	0		18.0		33		152	
231	2	400	30	23.0	22	90	44	42	.215	27.00	30	53	2400*	100	1	15.0	8.8	4	4	1	
231	2	268 +	21		6	-3	113					328	0	0		18.0		0		152	
232	2	400	30	23.0	22	88	44	42	.215	27.00	30	53	2400*	100	1	15.0	10.6	4	4	1	*
232	2	333 +	21		8	-3	216					344	0	0		18.0		0		152	
* EXTREMELY LARGE HOLE IN EXIT PLATE																					

02/16/72

TEST NO / TEST NO	TYPE TEST / SPEC TEST	FUEL TYPE / CRIT II	TANK TYPE / ULL ATMO	FUEL VOL (GAL)	TRAJ PHASE / CRIT III	TEMP FUEL (DEG F) / CRIT IV	TEMP AMB (DEG F) / CRIT V	(STRIKER (TYPE / (VIBRATION (FREQ (CPM)	THICK (IN) / AMP) (IN)	-- PLATE) SPACE (IN) / (SLOSH (FREQ (CPM)	ANGLE) (DEG) / AMP) (DEG)	(PROJECTILE) (TYPE / CRIT VI	VEL) (FPS) / CRIT VII	FILL TYPE / CRIT VIII	FIRE TYPE	TANK PRES (PSIA) / FUEL DEPTH (IN)	PRESS RISE (PSI)	TIME MAX P (S*100) / CRIT IX	INT REA	CRIT I / CRIT X	* SEE DATA SHEET
233	2	400	30	23.0	22	90	45	42	.215	27.00	30	53	2400*	100	1	15.0	12.2	3	4	1	
233	2	345+	21		8	-3	92					340	0	0		18.0		0		152	
234	2	400	30	23.0	22	90*	52	42	.215	27.00	30	53	2400*	100	1	15.0	9.0	4	4	1	
234	2	342+	21		8	-3	78					134	0	0		18.0		7		152	
235	2	400	30	23.0	22	90	53	42	.215	27.00	30	53	2400*	100	3	15.0	11.4	4	4	1	*
235	2	302+	21		7	-3	138					39	0	0		18.0		7		152	
* EXTERNAL FIRE APPEARED TO START AT REAR OF TANK AND SPREAD ALL OVER																					
236	2	400	30	23.0	22	90	52	42	.215	27.00	30	53	2400*	100	3	15.0	-1.0	-1	2	8	
236	2	0	21		1	-3	-1					-1	0	0		18.0		7		152	
237	2	400	30	23.0	22	90	55	42	.215	27.00	30	53	2400*	100	3	15.0	12.4	4	2	6	*
237	2	0	21		0	-3	-1					0	0	0		18.0		0		152	
* LARGE FIRE IN TANK AND STANDOFF - DAMAGE TO TANK AND PROJECTILE TRAP																					
238	2	400	30	23.0	22	90	54	42	.215	27.00	30	53	2400*	100	3	15.0	-1.0	-1	4	3	
238	2	0	21		8	-3	10					7	0	0		18.0		0		152	
239	2	400	30	23.0	22	90	54	42	.215	27.00	30	53	2400*	100	1	15.0	13.0	4	4	1	
239	2	356+	21		7	-3	174					74	0	0		18.0		0		152	
240	2	400	30	23.0	22	90	55	42	.215	27.00	30	53	2400*	100	1	15.0	14.6	4	4	3	
240	2	0	21		7	-3	17					11	0	0		18.0		7		152	
241	2	400	30	23.0	22	98	55	42	.215	27.00	30	53	2400*	100	2	15.0	10.0	3	4	3	
241	2	310 +	21		4	-3	57					25	0	0		18.0		7		152	
242	2	400	30	23.0	22	90	54	42	.215	27.00	30	53	2400*	100	1	15.0	9.8	4	4	3	
242	2	341 +	21		4	-3	157					16	0	0		18.0		7		152	

02/16/72

TEST NO / TEST NO	TYPE TEST / SPEC TEST	FUEL TYPE / CRIT II	TANK TYPE / ULL ATMO	FUEL VOL (GAL)	TRAJ PHASE / CRIT III	TEMP FUEL (DEG F) / CRIT IV	TEMP TWO (DEG F) / CRIT V	(STRIKER (TYPE / (VIBRATION (FREQ (CPM)	THICK (IN) / AMP) (IN)	-- PLATE) SPACE (IN) / (SLOSH (FREQ (CPM)	ANGLE) (DEG) / AMP) (DEG)	(PROJECTILE) (TYPE / CRIT VI	VEL) (FPS) / CRIT VII	FILL TYPE / CRIT VIII	FIRE TYPE	TANK PRES (PSIA) / FUEL DEPTH (IN)	PRESS RISE (PSI)	TIME MAX P (S*100) / CRIT IX	INT REA	CRIT I / CRIT X	* SEE DATA SHEET
243	2	400	32	23.0	22	90*	90	42	.215	27.00	30	53	2400*	100	1	15.0	20.0	16	1	-1	*
243	2	-1	21		-1	-3	123					254	0	0		18.0		0		152	
* FIRE IN STANDOFF AND OUT EXIT TUBE																					
244	2	400	32	23.0	22	90*	90	42	.215	27.00	30	53	2400*	100	3	15.0	40.8	20	5	-1	*
244	2	-1	21		-1	-3	171					560	0	0		18.0		0		152	
* LARGE EXTERNAL FIRE - FIRE IN STANDOFF AND TANK																					
245	2	400	32	23.0	22	90*	92	42	.215	27.00	30	53	2400*	100	1	15.0	4.0	3	1	-1	
245	2	-1	21		-1	-3	-1					0	0	0		18.0		0		152	
246	2	400	32	23.0	22	90	77	42	.215	27.00	30	53	2400*	100	3	15.0	22.2	16	1	-1	*
246	2	-1	21		-1	-3	110					274	0	0		18.0		4		152	
* EXTEREMELY LARGE FIRE - DAMAGE TO TANK AND EXHAUST TUBE DUCT																					
247	2	400	32	23.0	22	90	90	42	.215	27.00	30	53	2400*	100	1	15.0	8.6	14	1	-1	
247	2	-1	21		-1	-3	97					159	0	0		18.0		0		152	
248	2	400	32	23.0	22	90	73	42	.215	27.00	30	53	2400*	100	1	15.0	9.6	17	1	-1	
248	2	-1	21		-1	-3	177					97	0	0		18.0		0		152	
249	2	400	32	23.0	22	90	83	42	.215	27.00	30	53	2400*	100	1	15.0	6.4	4	1	-1	
249	2	-1	21		-1	-3	153					74	0	0		18.0		4		152	
250	2	400	32	23.0	22	90	93	42	.215	27.00	30	53	2400*	100	1	15.0	7.0	4	1	-1	
250	2	-1	21		-1	-3	17					0	0	0		18.0		4		152	
251	2	400	32	23.0	22	95	90	42	.215	27.00	30	53	2400*	100	1	15.0	9.4	4	1	-1	
251	2	-1	21		-1	-3	176					91	0	0		18.0		4		152	
252	2	400	32	23.0	22	90	90	42	.215	27.00	30	53	2400*	100	1	15.0	8.2	4	1	-1	
252	2	-1	21		-1	-3	254					99	0	0		18.0		0		152	

02/16/72

TEST NO	TYPE TEST	FUEL TYPE	TANK TYPE	FUEL VOL (GAL)	TRAJ PHASE	TEMP FUEL (DEG F)	TEMP TNK (DEG F)	(STRIKER (TYPE	THICK (IN)	-- PLATE SPACE (IN)	) ANGLE) (DEG)	(PROJECTILE) (TYPE	VEL) (FPS)	FILL TYPE	FIRE TYPE	TANK PRES (PSIA)	PRESS RISE (PSI)	TIME MAX P (S*100)	INT REA	CRIT I	* SEE DATA SHEET
TEST NO	**SPEC TEST**	**CRIT II**	**ULL ATMO**		**CRIT III**	**CRIT IV**	**CRIT V**	**(VIBRATION (FREQ) (CPM)**	**) AMP) (IN)**	**(SLOSH (FREQ) (CPM)**	**) AMP) (DEG)**	**CRIT VI**	**CRIT VII**	**CRIT VIII**		**FUEL DEPTH (IN)**		**CRIT IX**		**CRIT X**	
253	2	400	32	23.0	22	45	65	42	.215	27.00	30	53	2400*	100	1	15.0	22.4	11	1	-1	
253	2	-1	21		-1	-1	46					155	0	0		18.0		4		152	
254	2	400	32	23.0	22	83	69	42	.215	27.00	30	53	2400*	100	1	15.0	31.2	11	1	-1	
254	2	-1	21		-1	-3	80					366	0	0		14.0		4		152	

APPENDIX II

POSSIBLE CONTAMINATION OF JP-8 TEST BY PREVIOUS JP-4 TEST

Although it was standard procedure to completely wash the test article with water between tests to remove all fuel and fuel vapor, it was of concern that the first shot in a JP-8 test series may in some way be contaminated by the previous JP-4 test series. To investigate this possibility, the standoff pressure rise of several "first shots" of a JP-8 series which were preceded by a JP-4 shot was compared to the standoff pressure rise of the "last shots" of the several JP-8 series of interest. The results of the analysis is shown by Table XIII. Since no significance is shown, we concluded that the JP-8 tests were not contaminated by previous JP-4 tests and the water wash was sufficient.

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TABLE XIII

MAXIMUM STANDOFF PRESSURE OF
FIRST VERSUS LAST JP-8 SHOT OF A SERIES

First Test		Last Test	
Test No.	Pressure Rise (psi X 10)	Test No.	Pressure Rise (psi X 10)
13	167	18	27
25	87	30	113
43	44	48	76
64	38	68	6
80	40	85	58
128	32	133	48
163	32	168	48
Variance	2515		1181
Mean	62		54
F Ratio - 2.1	T Value - 0.43	T_c - 1.78	

APPENDIX III

OXYGEN DILUTION DUE TO INCENDIARY FUNCTIONING

The projectile velocity, impact angle, and strike plate thickness were determined by tests to provide maximum functioning in the dry bay of the incendiary mix associated with the CAL .50 API. This was done to provide the "biggest match" possible for fuel ignition in the dry bay. Since the incendiary is fuel rich, some oxygen in the dry bay may enter into the reaction. In addition, the products of the reaction may tend to dilute the oxygen concentration. If the oxygen concentration is reduced to below 12% by volume, no fuel reaction can be expected (Reference 4). The following analysis addresses these questions as a first approximation, and the results are presented in Figure 13. As may be seen in this figure, all the test articles and associated dry bays used in this program should have had sufficient oxygen to support a fuel reaction. This figure gives minimum values of O_2 remaining, and since only a small part of the incendiary reacts in the dry bay, the results are conservative. The following calculations were used to develop Figure 13.

The incendiary mix, IM-11, of the CAL .50 API weights 1.0 gram and has the following composition:

50% by weight	$Ba\ (NO_3)_2$
25% by weight	Mg
25% by weight	Al

For complete combustion of the incendiary mix the following reaction must be considered:

$$Ba + 1/2\ O_2 \rightarrow Ba\ O$$
$$Mg + 1/2\ O_2 \rightarrow Mg\ O$$
$$2\ Al + 3/2\ O_2 \rightarrow Al_2\ O_3$$

Gram Moles initially present in 1.0 gm of incendiary

$$\frac{.5 \text{ gms. Ba } (NO_3)_2}{261.3 \text{ gms./gm. mole Ba } (NO_3)_2} = 1.92 \times 10^{-3} \text{ g. moles Ba } (NO_3)_2$$

$$\frac{.25 \text{ gms. Mg}}{24.3 \text{ gms./gm mole Mg}} = 1.027 \times 10^{-2} \text{ gm moles Mg}$$

$$\frac{.25 \text{ gms. Al}}{26.98 \text{ gms./gm mole Al}} = 0.927 \times 10^{-2} \text{ gm moles Al}$$

gm moles O_2 present in 0.5 gm of Ba $(NO_3)_2$

$$\frac{3 \text{ moles } O_2}{1 \text{ mole Ba } (NO_3)_2} \times 1.92 \times 10^{-3} \text{ gm moles Ba } (NO_3)_2$$

$$= 5.76 \times 10^{3} \text{ gm moles } O_2$$

gm moles N_2 present in 0.5 gm of Ba $(NO_3)_2$

$$\frac{1 \text{ mole } N_2}{1 \text{ mole Ba } (NO_3)_2} \times 1.92 \times 10^{-3} \text{ gm moles Ba } (NO_3)_2$$

$$= 1.92 \times 10^{-3} \text{ gm moles } N_2$$

Total gm moles O_2 required for complete reaction

Ba requires	.00096	gm moles O_2
Mg requires	.00513	gm moles O_2
Al requires	.00695	gm moles O_2
	.01304	Total gm moles O_2 required

Total gm moles of additional O_2 required from the air

.01304	total gm moles O_2 required
-.00576	gm moles O_2 existing in mix
.00728	additional gm moles O_2 required

Vol. of O_2 needed from air at 25°C per 1 gm incendiary

$$V_{O_2} = \frac{nRT}{P}$$

$$V_{O2} = (.00728 \text{ gm moles } O_2 \text{ reguired})$$

$$\left(\frac{.08205 \text{ atm - liter}}{\text{gm mole - °K}}\right)\left(\frac{.0353 \text{ ft}^3}{\text{liter}}\right)\frac{(296°K)}{(1 \text{ atm})}$$

$$V_{O2} = 6.28 \times 10^{-3} \text{ ft}^3 \text{ needed from air}$$

Vol. of N_2 released during reaction at 2000°K

$$V_{N2} = (.00192 \text{ gm moles } N_2 \text{ released})$$

$$\left(\frac{.08205 \text{ atm - liter}}{\text{gm mole - °K}}\right)\frac{(2000°K)}{(1 \text{ atm}))}\left(\frac{.0353 \text{ FT}^3}{\text{liter}}\right)$$

$$V_{N2} = .0111 \text{ ft}^3 \; N_2 \text{ released}$$

Since the following oxides will be solids they will not dilute the dry bay oxygen:

Al_2O_3	Boiling Point = 3500°C
Ba 0	Boiling Point = 2000°C
Mg 0	Melting Point = 2800°C

Now let V_R = the final O_2 volume % in the dry bay - FT^3
V_D = Volume of the dry bay - FT^3

$$V_R = \frac{.21\, V_D \text{ (initial } O_2 \text{ Vol.) - .00628 FT}^3 \text{ (}O_2 \text{ needed from air)} \times 100\%}{V_D - .00628 \text{ FT}^3 \text{ (}O_2 \text{ needed from air) + .0111 FT}^3 \text{ (}N_2 \text{ released)}}$$

$$\boxed{V_R = \frac{21\, V_D - .628}{V_D + .00482}}$$ This equation was used to develop Figure 13.

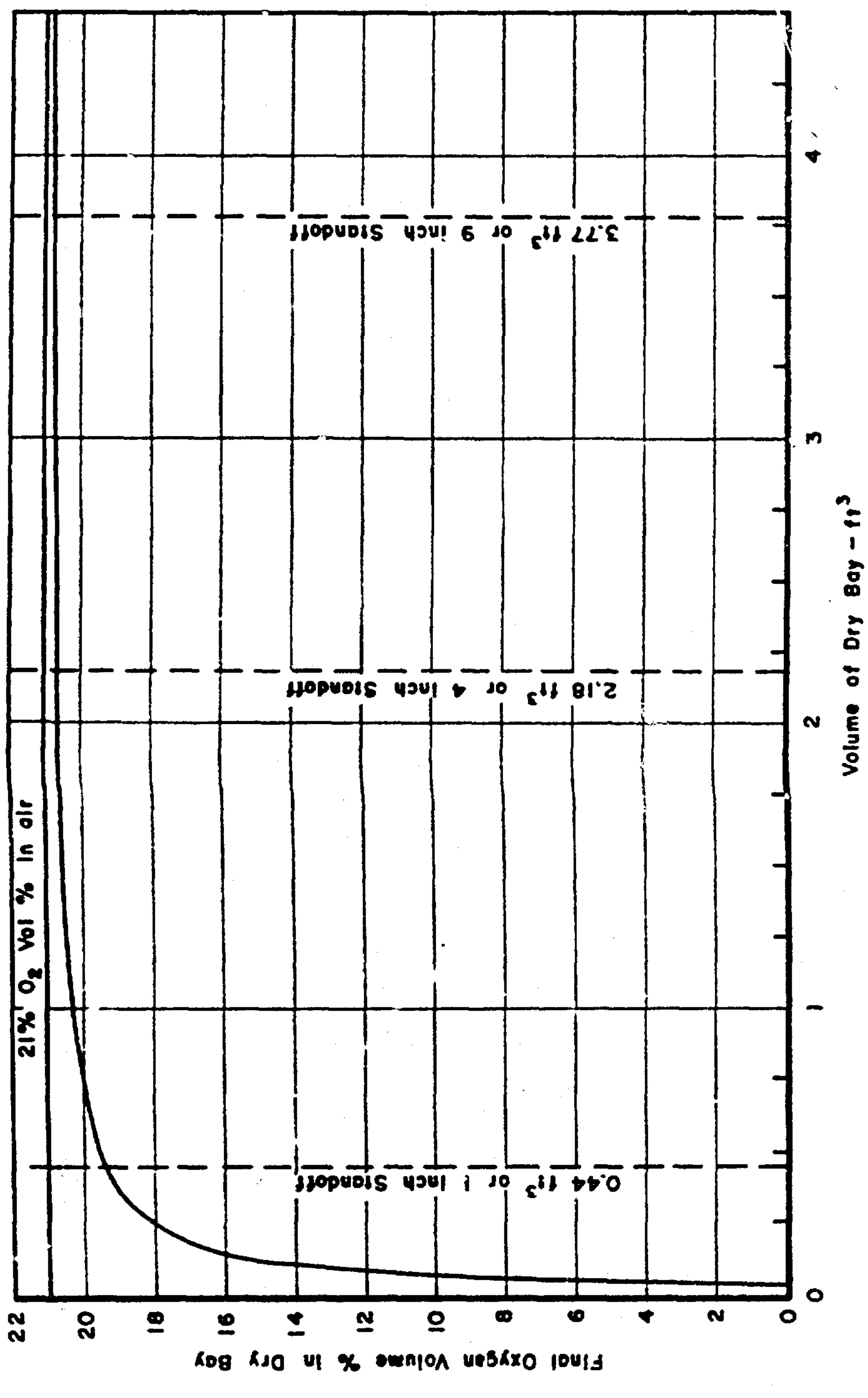

Figure 13. Final Oxygen Volume Percent in Dry Bay After Incendiary Reaction

APPENDIX IV

SAMPLE STATISTICAL PROBLEM

We generated a sample set of data to obtain some insight into the results that could be expected from the use of statistical methods. Twelve random numbers (A in Table XIV) were selected, ranging from 0 to 35, which was the expected range of overpressure for the standoff volume. The numbers for comparison were defined as B = 0.6A. Therefore, by definition, the difference between any set of A and B numbers was 40%. It was then assumed four tests were conducted giving the first two responses of both A and B. A statistical analysis was performed on the results. This was repeated assuming eight additional tests. In the final step it was assumed that twelve more tests were conducted. The statistical results for the sample problem are given in Table XIV. As may be seen, the defined difference between A and B was not shown in the calculated T value until all 24 tests were conducted.

Another sample problem was also conducted (results not shown) with the same values of A but with B = 0.8A. The same procedure was applied, and even after 24 tests the T value did not show the defined 20% difference between A and B as significant.

The foregoing example was generated to illustrate that it is difficult to prove with high confidence a difference between two fuels if that difference is relatively small and only a limited number of tests are conducted; the smaller the difference, the more tests are required to prove a significant difference.

TABLE XIV

SAMPLE STATISTICAL PROBLEM (RANDOM NUMBERS 0 TO 35)
B = 0.6A (BY DEFINITION)

No.	Test Description		VARIANCE		MEAN		F Ratio	T Value	T_c	REMARKS
	A	B	A	B	A	B				
1	34.0	20.4								
	14.0	8.4	200.0	72.0	24.0	14.4	2.78	1.43	2.92	Based on 4 tests
2	11.0	6.6								
	18.0	10.8								
	2.0	1.2								
	7.0	4.2	123.5	44.4	14.3	8.6	2.78	1.28	1.81	Based on 12 tests
3	17.0	10.2								
	19.0	11.4								
	1.0	0.6								
	30.0	18.0								
	11.0	6.6								
	12.0	7.2	98.6	35.5	14.7	8.8	2.78	1.91	1.72	Based on 24 tests

APPENDIX V

PROPERTIES OF JP-4 AND JP-8 FUELS

At the present time the United States Air Force uses JP-4 (Commercial Designation: JET B), a wide-cut distillate fuel, as its preferred operational fuel. JP-4 was adopted back in the early 1950's, and its properties were selected to maximize worldwide availability while fulfilling aircraft operational performance requirements. The proposed replacement fuel, JP-8, has lower volatility, and its properties were determined by worldwide availability, operational performance, and fire safety considerations. The comparative properties of JP-4 and JP-8 are given in Table XV.

TABLE XV

PROPERTIES OF JP-4 AND JP-8 FUELS

	JP-4*	JP-8*	JP-4 SPEC.	PROPOSED JP-8 SPEC.
Flash Point (°F)	-20	118	----	105-150
Distillation (°F)				
(a) Initial Boiling Point	140	314	----	----
(b) End Point	455	508	----	550
*Gravity (°API)	54.4	43.8		39-51
Freeze Point (°F)	-80	-65	-76 max.	-54 max.
Aromatics	11.4	16	25 max.	25 max.
Olefins	1	2	----	5 max.
Viscosity (Centistokes at - 30°F)	2.4	8	----	15 max.
Reid Vapor pressure (psi at 100°F)	2.6	<0.1	2.0-3.0	----
Density (lbs/gal)	6.41	6.81	6.25-6.68	6.46-6.91
Heat of Combustion				
(a) BTU/lb	18,714	18,559	18,400 min.	18,400 min.
(b) BTU/gal	119,957	125,830	----	----
Autoignition Temp. (°F)	~484 min.	~473	----	----
Burning Velocity-Vapor-Air Mixture (ft/sec)	~1-2	~1-2	----	----
Flame Spread Rate, Quiescent Liquid, 80°F (ft/min)	~750	~25	----	----

* TYPICAL OF FUEL USED IN FAA TEST PROGRAM

REFERENCES

1. G. W. Gandee "Evaluation of Fire Safe Fuels," paper presented at the Industry-Military Jet Fuel Quality Symposium, October 22, 23, and 24, 1968, San Antonio, Texas.

2. AFAPL-TR-70-93, AFAPL Aircraft Fire Test Program with FAA, 1967-1970, June 1971.

3. APFH-TM-70-34, "Evaluation of JP-8 Versus JP-4 Fuel for Enhancement of Aircraft Combat Survivability," June 1970.

4. AFAPL-TR-70-82, Influence of Fuel Slosh Upon the Effectiveness of Nitrogen Inerting for Aircraft Fuel Tank, February 1971.